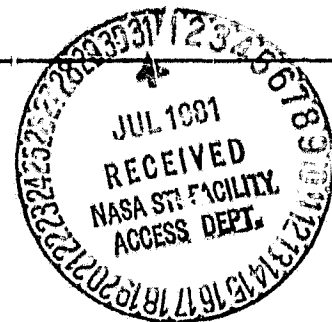


## N O T I C E

THIS DOCUMENT HAS BEEN REPRODUCED FROM  
MICROFICHE. ALTHOUGH IT IS RECOGNIZED THAT  
CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED  
IN THE INTEREST OF MAKING AVAILABLE AS MUCH  
INFORMATION AS POSSIBLE



**SONO<sup>TM</sup> SCAN INC**



**EXAMINATION OF SILICON SOLAR CELLS  
BY MEANS OF  
THE SCANNING LASER ACOUSTIC MICROSCOPE (SLAM)**

(NASA-CR-154579) EXAMINATION OF SILICON  
 SOLAR CELLS BY MEANS OF THE SCANNING LASER  
 ACOUSTIC MICROSCOPE (SLAM) (Sonoscan, Inc.)  
 66 p HC A04/MF A01 CSCI 10A  
 G3/44 26918 Unclas  
 N81-27615

Submitted To:	Paul M. Stella Photovoltaic Space Systems Group Solar Energy Conversion Systems Section Jet Propulsion Laboratory California Institute of Technology 4800 Oak Grove Drive Pasadena, CA 91103
Submitted By:	Sonoscan, Inc. 530 East Green Street Bensenville, IL 60106 (312) 766-7088
Performed Under the Direction of:	Paul Stella
Prepared By:	Carol Vorres, MTS Donald E. Yuhas, MTS

Contract No. 955910

REPORT #R117

April 28, 1981

" This work was performed for the Jet Propulsion Laboratory, California Institute of Technology and was sponsored by the National Aeronautics and Space Administration."

## TABLE OF CONTENTS

- I. Introduction
- II. The Scanning Laser Acoustic Microscope
- III. Acoustic Microscope Data
- IV. Quantitative Interpretation Of Micrographs
- V. Evaluation Of Silicon Solar Cells By Means  
Of The SLAM
- VI. Results
  - A. Phase I - Tab -less Cells and Handling Procedure
  - B. Phase II - Welded Tabs on Cells A-
  - C. Phase III - Welded Tabs on Cells S-
  - D. Phase IV - Cell C1C1

## INTRODUCTION

The Scanning Laser Acoustic Microscope (SLAM) produces images of internal structure in materials. Traditional methods for characterizing microstructure employ a variety of instruments and techniques, such as optical and electron microscopy and x-microradiography. The common denominator of these methods is that the images are produced by interacting electromagnetic radiation with the specimen. Thus, structures are visualized only if there are changes in the electromagnetic properties, such as dielectric constant or conductivity. In contrast, the acoustic microscope is an imaging system based upon acoustic rather than electromagnetic waves. Thus, variations in the elastic properties are primarily responsible for structure visualized in acoustic micrographs.

Acoustic waves are a form of mechanical energy and, therefore, they are reflected, refracted and scattered at interfaces, structures, and inclusions where the mechanical characteristics are perturbed. The propagation and attenuation of acoustic waves are governed by physical properties, such as mass density, elastic modules, viscosity, and viscoelasticity of the material under investigation. Thus, the physical properties responsible for the acoustic images are different from those responsible for images obtained using waves from the electromagnetic spectrum. Real-time acoustic visualization of silicon solar cells may provide a means for the rapid, nondestructive characterization of these components.



## THE SCANNING LASER ACOUSTIC MICROSCOPE

The instrument used in these investigations is the SONOMICROSCOPE 100 which can be operated at ultrasonic frequencies of from 30 MHz to 500 MHz. The examination of the silicon solar cells was made at 100 MHz. Below is a brief description of the important features of the microscope. This is given to facilitate interpretation of the acoustic micrographs presented in the report.

The basic insonification geometry and detection scheme employed by the SLAM is illustrated in Figure 1. Ultrasonic energy is incident on the sample from below. An insonification angle of  $10^\circ$  (in water) is commonly used, however, this parameter is variable. The transmitted acoustic energy imparts a slight oscillatory mechanical motion to the sample's top surface. These oscillations have the same frequency as the incident wave, but vary in amplitude depending on the acoustic attenuation and absorption properties of the underlying material. These disturbances are detected, point by point, by a rapidly scanning focused laser beam (40,000 image points per micrograph) which drives an optoacoustic receiver. The acoustic image is then displayed on the TV monitor where the white regions correspond to areas of the sample with good acoustic transmission properties, while the darker areas of the micrographs are regions of higher ultrasonic attenuation. If the sample has a good surface finish, an acoustic image can be obtained from the light specularly reflected directly from the surface. When this is not the case, a mirrored coverslip is placed in acoustic contact with the top surface of the sample and light reflected from the coverslip is used to form the acoustic image.

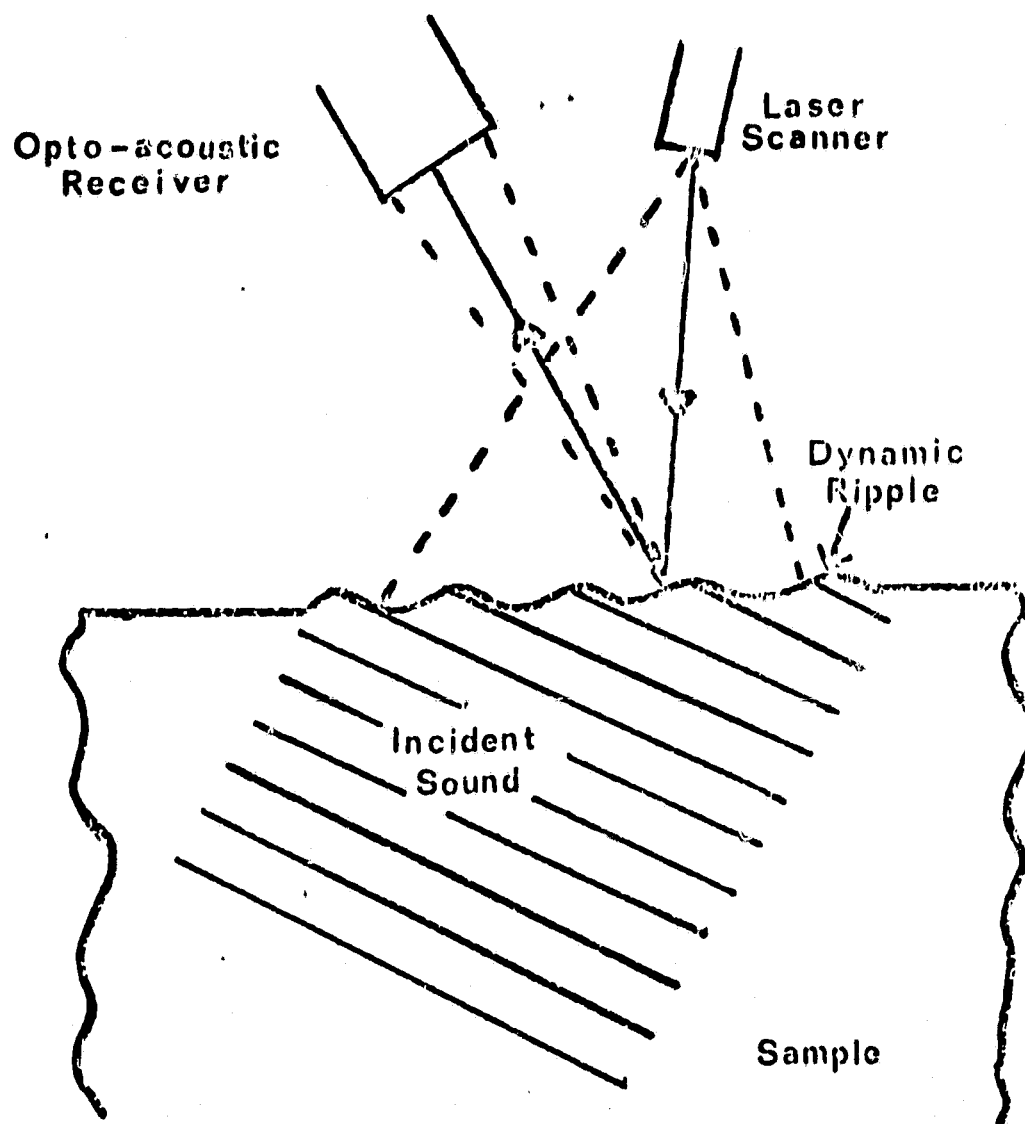
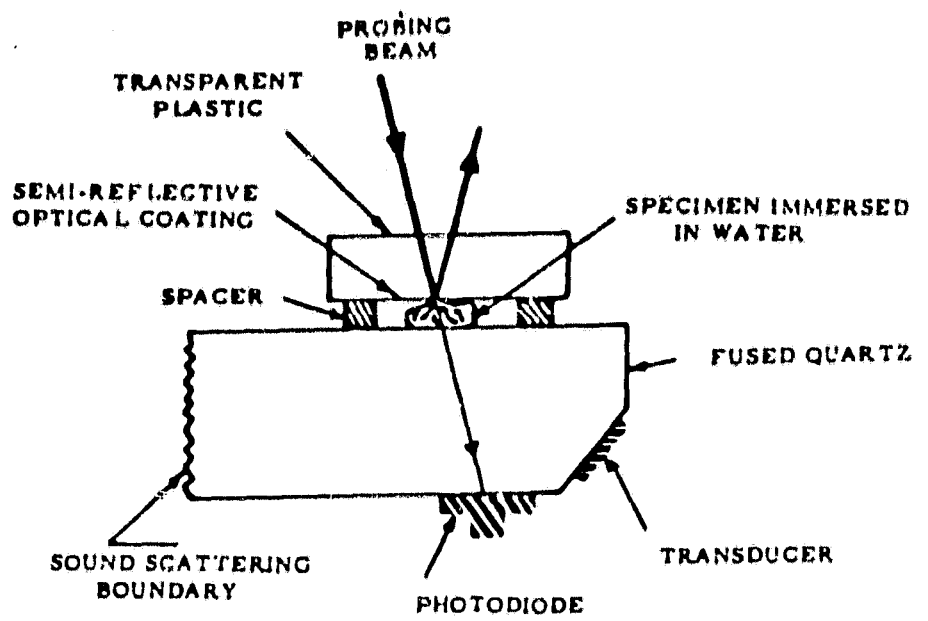


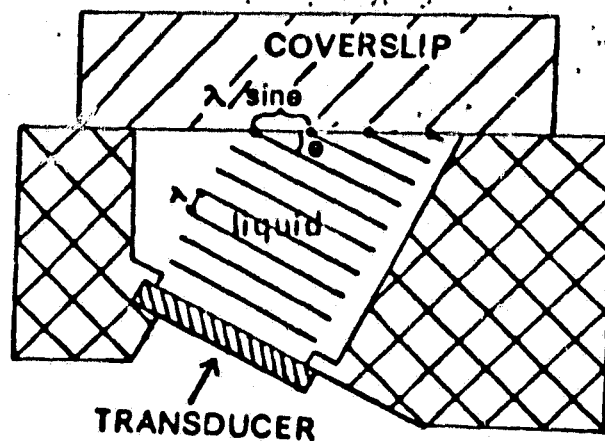
FIGURE 1

ORIGINAL PAGE IS.  
OF POOR QUALITY

Acoustic energy is brought to the sample by the microscope stage. There are two basic types of stages which are commonly used for flat samples. In the "glass cell", illustrated in Figure 2a, a transducer is bonded to a glass block which serves as a support for the sample. The liquid cell is illustrated in Figure 2b, here the conduction of sound from transducer to sample is through a liquid which fills the chamber. In this work a liquid cell was used.



a)



b)

FIGURE 2

## ACOUSTIC MICROSCOPE DATA

Data are presented in the form of photomicrographs. The four image modes, available with the SONOMICROSCOPE 100, are described below.

There are two types of acoustic amplitude pictures. First are amplitude pictures made at a single ultrasonic frequency. These acoustic micrographs are generally characterized by a substantial amount of contrast and may be subject to coherent speckle. The amount of speckle is related to the degree of scattering in the specimen and provides some indication of both the mode of acoustic loss, as well as the elastic microstructure of the material under investigation. The second type of amplitude picture is obtained by sweeping the frequency around 100 MHz. This eliminates coherent speckle and reveals features often masked by the speckle.

In addition to displaying the acoustic amplitude distribution throughout the field of view, the SONOMICROSCOPE provides an acoustic interference mode of operation. Acoustic interferograms show a series of alternating light and dark stripes. For acoustically homogeneous samples these bands (interference fringes) are parallel to one another and are equally spaced. For samples that are elastically inhomogeneous, the interference lines will be distorted by localized variations in the sound velocity and/or sample thickness. Quantitative velocity measurements may be obtained from the interferograms using the formula given in the application note, which is included in the appendix of this report. All of the interferograms included in this report are oriented so that fringe shift to the right corresponds to an area of lower ultrasonic velocity and shifts to the left indicate regions of higher sonic velocity. Because many of the samples investigated

( in this report have controlled thicknesses, the character of the interferograms is determined solely by localized variations in the velocity of sound. These variations are related to either variations in the bulk density or elastic modulus of the sample constituents.

Lastly, in samples which are not optically opaque, good optical transmission images can be obtained. Optical reflection micrographs can also be obtained. In some cases, the use of coherent laser illumination and special optical detection schemes leads to enhanced image contrast.

The switching to any of the visualization modes is accomplished electronically, thus, no repositioning of the sample is required.

## Quantitative Interpretation Of Micrographs

The quantitative aspects of acoustic microscopy analysis involve determination of localized (regional) variations in elasticity and density. These parameters can be calculated from measurements made with the acoustic microscope. The needed measurements are: (1) the velocity of sound (the reciprocal of the index of refraction) and (2) the acoustic attenuation level within the region of interest. The velocity of sound is determined from a graphical measurement of the lateral fringe displacements on the interferogram. The acoustic attenuation can be determined by quantifying the brightness levels on the CRT display.

In the acoustic microscope, acoustic attenuation measurements are made by means of a comparison technique. With the sample in place and the acoustic image displayed on the CRT, the appropriate region of interest is selected. Positive identification of the area is made with the assistance of the corresponding optical image as well. The relative image brightness in this region, compared to that when no material is present, is a measure of the attenuation. Experimentally, an image brightness level is established on the CRT with a light meter confined to the field of interest of the sample. With the sample removed, the microscope is again focused on the illuminating sound field alone. Known values of electrical attenuation are then inserted into the signal path of the insonification transducer in order to restore the brightness to the previous level. The inserted electrical attenuation is equal to the acoustic attenuation caused by the sample. This method has been substantiated by measuring the attenuation coefficients in known materials.

The principle by which measurements of velocity of sound are made on the acoustic interferograms can be explained as follows: consider the intersection of two coherent plane waves of sound at a detector plane, viz., the coverslip. Depending upon the angle between the two beams a series of regularly spaced fringe lines, caused by mutual interference, will occur. If an object, with velocity of sound characteristics different from the surrounding medium interrupts only one of the beams, refraction will occur and localized shifts of the fringe lines will appear. The measured displacement of a fringe is related to the disturbance in phase or transmission time of one beam compared with the unperturbed beam.

A simple formula has been derived to calculate the velocity of sound in an "unknown" sample. In the acoustic microscope the geometry required by the high acoustic attenuation precluded two acoustic beams. Instead, the reference beam is simulated electronically at normal incidence, and the acoustic beam is angled slightly with respect to the normal. According to Snell's Law, an acoustic beam incident upon the sample at angle  $\theta_o$  from the normal will be refracted to angle  $\theta_x$  within the sample according to this relationship:

$$\frac{\sin \theta_o}{C_o} = \frac{\sin \theta_x}{C_x}$$

where  $C_o$  and  $C_x$  are the velocities of sound in the surrounding medium and the sample, respectively. If the thickness of the sample, or of the region of interest, i.e., inclusion, is denoted by  $\Delta T$ , then the lateral shift of the fringes, normalized by the unperturbed spacing of the fringes  $N$ , is given by:

$$N = \frac{\Delta T \sin \theta_o}{L_o} \left[ \frac{1}{\tan \theta_o} - \frac{1}{\tan \theta_x} \right]$$



where  $L_0$  is the wavelength of sound in the surrounding material or the microscope stage. Note that  $N$  is a dimensionless number, corresponding to the number of fringes of shift in the interferogram. By solving for  $\theta_x$  and then using the Snell's Law relationship,  $C_x$  is readily calculated. Typically  $\theta_0$  is  $10^\circ$ , however, it depends upon the particular configuration of the stage employed.

EVALUATION OF SILICON SOLAR CELLS  
BY MEANS OF  
THE SCANNING LASER ACOUSTIC MICROSCOPE (SLAM)

Samples were sent to Sonoscan in three intervals. The first group contained 10, 2 mil solar cells having no welded tabs. These were primarily used for developing a sample handling procedure. Three of the cells were labeled A- and the remaining seven were labeled S- depending on the manufacturer.

The second set of samples consisted of 13 cells each having 2 welded tabs. These were all labeled S-.

The third batch of samples contained cells labeled both A- and S- (total 17). Also included in this set was a sample labeled C1C1 which contained a glass cover RTV'd to the solar cell. This cell contained 4 tabs, 2 bonded to the top surface and 2 on the underside. Sample A-7 contained 2 tabs bonded to the underside body of the solar cell (as opposed to being bonded to pads).

The report is divided into four phases. The first phase described a handling procedure developed on the tab-less cells and includes acoustic micrographs of each of these samples. Phase II contains micrographs taken on the samples labeled A-. Phase III contains micrographs from the samples labeled S-. Phase IV contains micrographs taken on the C1C1 sample having the glass cover.

## RESULTS

We anticipate the high level of acoustic transmission in conjunction with uniformity of the phase of the wave across the bond interface indicates well bonded zones. Clearly the area of the bonded zone as well as the quality of sound transmission (e.g. brightness, fringe uniformity), should correlate with bond integrity. However, a number of other aspects of the bonds may need to be considered. Our observations indicate that the weld process is highly non-uniform in terms of:

- a) weld nugget size
- b) quality of acoustic transmission
- c) number of distinct contact points
- d) location of nuggets on weld pad
- e) shape of weld nuggets
- f) placement of tab on bonding pad

As a result 100% documentation was required. Further analysis of this data should be guided by correlation with life tests and/or known variations in the weld parameters.

## PHASE I

The initial phase of this evaluation was to describe a handling procedure for the two mil solar cells. Ten cells were sent to Sonoscan for this purpose, A1, A2, A3, S1 - S7. Though none of the cells has tabs welded at this time, each contains two areas where tabs can be welded.

Also included in this section of micrographs is sample A-17 which arrived with the third set of samples, but contained no welded tabs.

Sample A1 was thermally stressed after its initial examination on the SLAM. Micrographs are included in this section of before and after thermal stressing.

### HANDLING PROCEDURE:

1. Set up SONOMICROSCOPE according to operator manual.
2. Using the 10<sup>0</sup> liquid cell, place distilled H<sub>2</sub>O (coupling fluid) on the transducer and move coverslip\* as close as possible to the transducer. (The solar cell will fit between the transducer and the coverslip.)
3. Turn on the sound and check focus; adjust, if necessary.
4. Lift the solar cell from its holder using a moist Q-tip. Record the number of the cell. Place an index card under the cell to keep it from being dropped.
5. Sweep the cell onto the SLAM stage with a tiny soft paintbrush. The tab weld area should be on the side closest to the coverslip for maximum detailed imaging.
6. Using the paintbrush, slide the solar cell between the transducer and coverslip. Rotate the cell for maximum transmission and least reverberation.
7. Record data on area a), and then on area b), noting:
  - 1) size of weld area; 11) relative acoustic transmission level.

8. Slide the solar cell onto lens paper to absorb the water and place back in its holder, handling gently with paintbrush and index card.

\*Note: When using a partially mirrored coverslip, simultaneous optical and acoustic images can be obtained.

The ten cells were handled using this procedure and micrographs were taken in the a and b areas of each tab which follow:

SUMMARY OF 10 CELLS WITH NO TABS

<u>Cell</u>	<u>Area</u>	<u>Description</u>
A1	a	<u>cracks</u> extending in pad area
	b	fairly clean
A1a	a	(after thermal stressing) crack changed slightly
	b	(after thermal stressing) crack now present
A2	a	<u>chips</u> on the edges of pad, but both have excellent
	b	acoustic transmission
A3	a	both have excellent transmission
	b	
A-1/	a	excellent transmission
	b	transmission poor
S1	a	both areas very attenuating (b)
	b	with more structure than (a)
S2	a	(a) more attenuating than (b),
	b	both have much structure
S3	a	both attenuating; (b) more than (a)
	b	
S4	a	both have much structure
	b	much structure
S5	a	contains 2 areas of delaminations
	b	much structure

SUMMARY OF 10 CELLS WITH NO TABS

<u>Cell</u>	<u>Area</u>	
S6	a	both contain much structure
	b	
S7	a	both are <u>extremely</u> attenuating
	b	



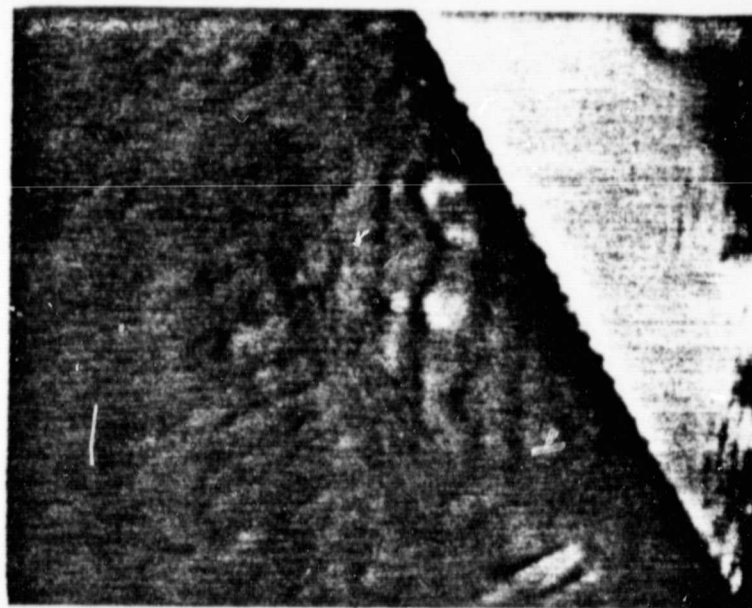
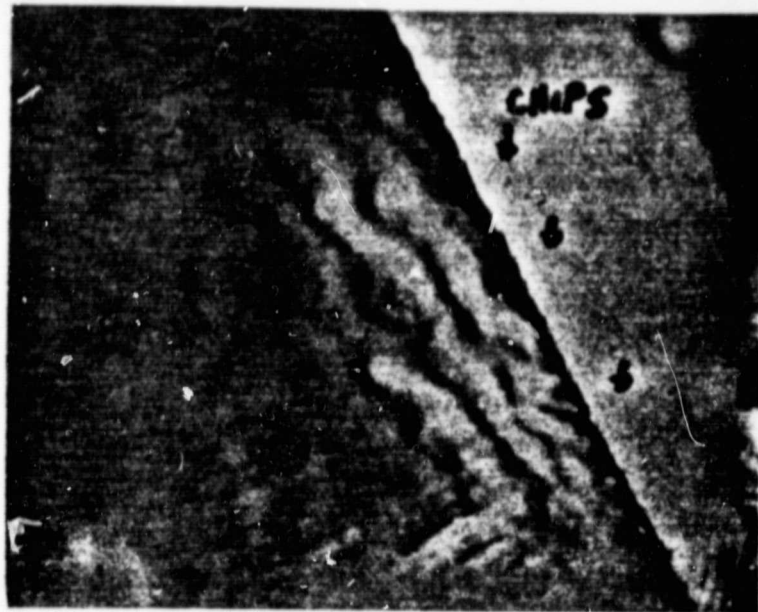
ORIGINAL PAGE IS  
OF POOR QUALITY

A-1 - Acoustic amplitude micrographs taken in area (a) top and (b) bottom of solar cell A1. Good acoustic transmission occurred through these areas. A crack was found in (a). Reverberation lines are seen due to the thin samples not being flat. Real time imaging prevents misinterpretation of these artifacts.

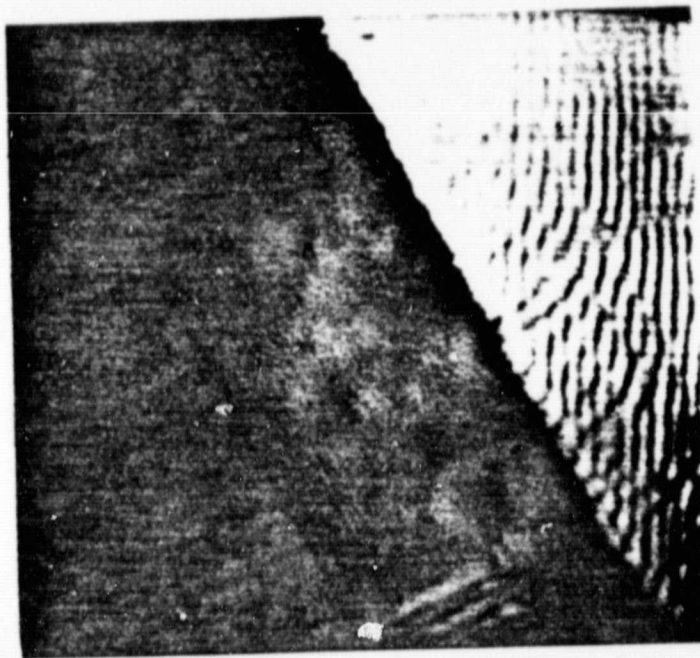
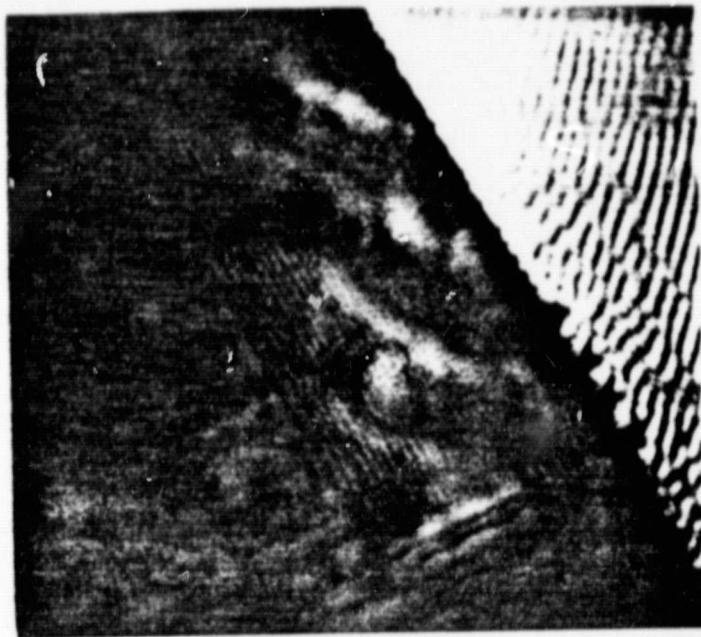


A-1. These acoustic micrographs were taken on cell A-1 after some thermal cycling. Compare these micrographs with the ones taken before and notice especially the crack in the "b" pad which was not visible earlier.





A-2 - Acoustic amplitude micrographs taken on areas (a) top and (b) bottom of solar cell A2. Good transmission occurs in both of these areas. Near the edge of the sample, some structure is seen which is probably the result of some chipping of the material.

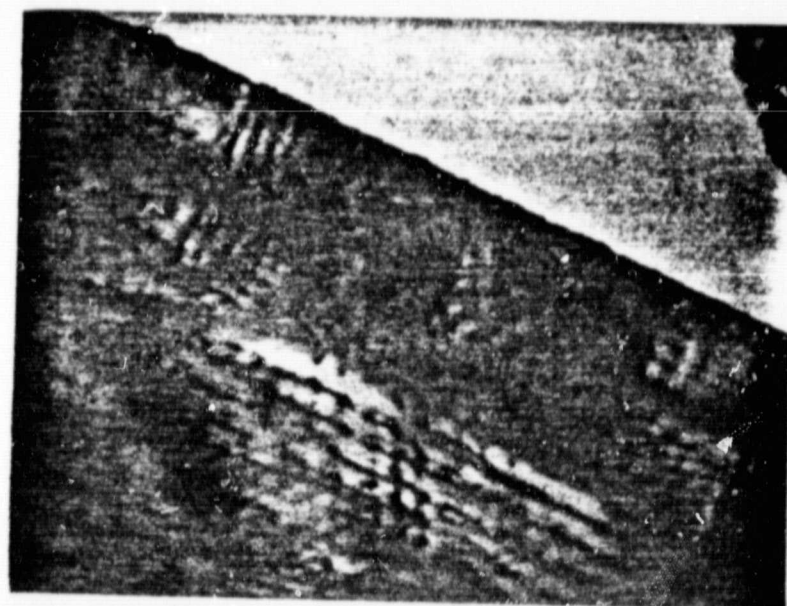
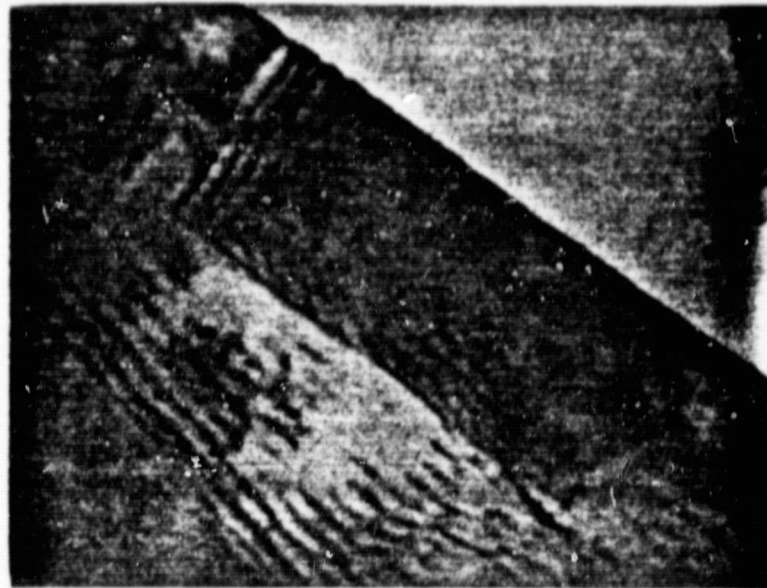


ORIGINAL PAGE IS  
OF POOR QUALITY

A-3 - Excellent transmission occurs in both the (a) top and (b) bottom areas of cell A-3 as seen in these micrographs. These appear to be the best from the A group of solar cells.

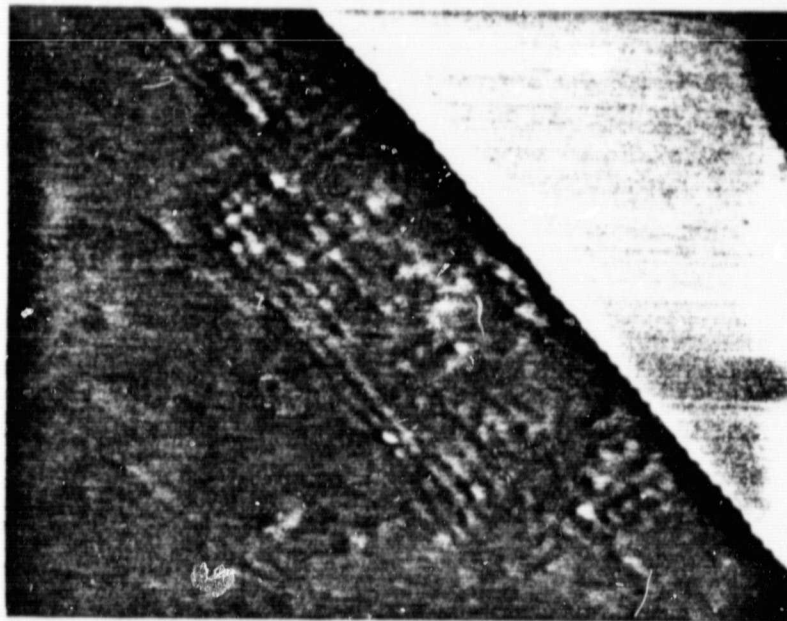
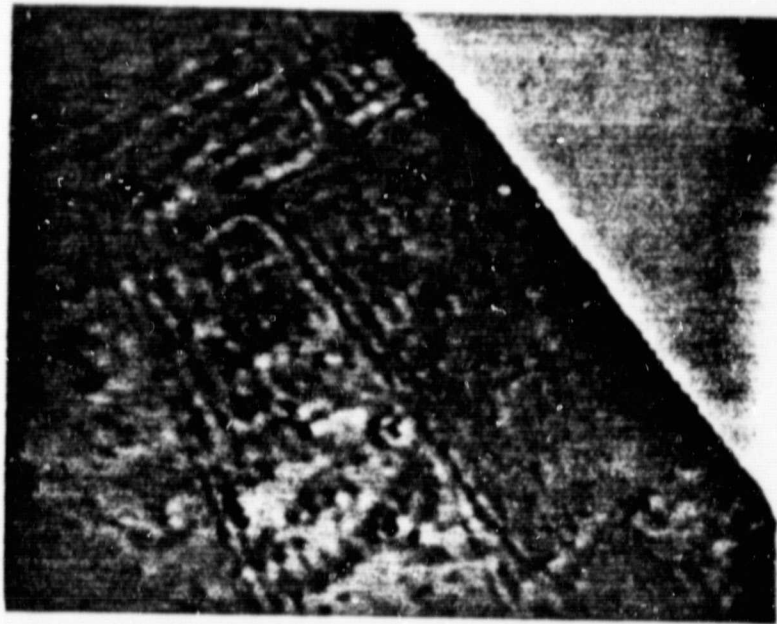


A-17. Neither pad on this solar cell had a tab welded to it. Area a (top) exhibits much better acoustic transmission than area b (bottom).



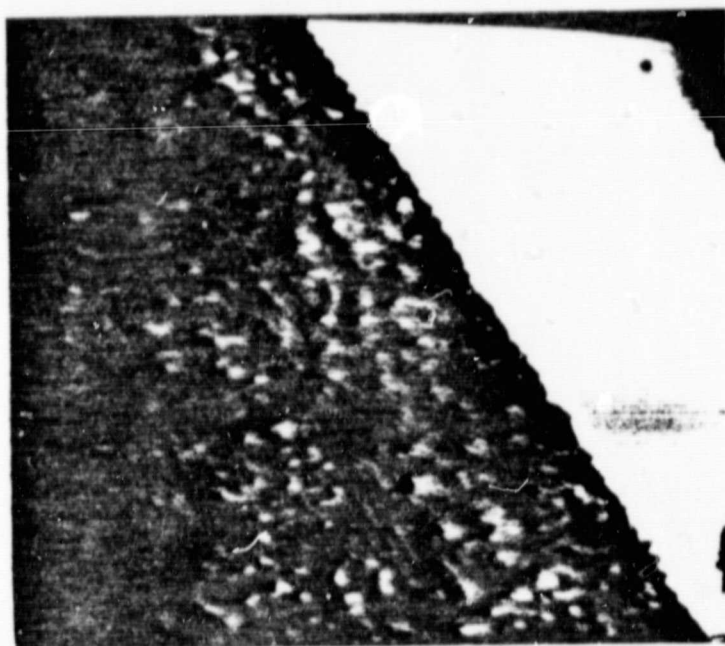
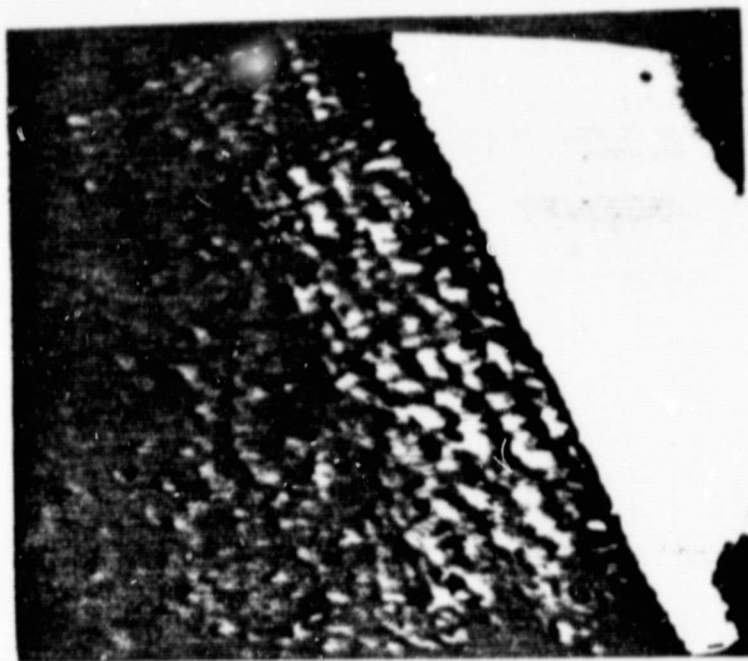
S-1 - Acoustic amplitude micrographs taken on solar cell S-1. The top was taken on area (a) and the bottom from area (b). Both are much more attenuating than the weld areas of the A 1-3 tabs. (b) also contains a great deal of structure. This attenuation difference could be due to the metallization or the bonding of the pad to the cell.



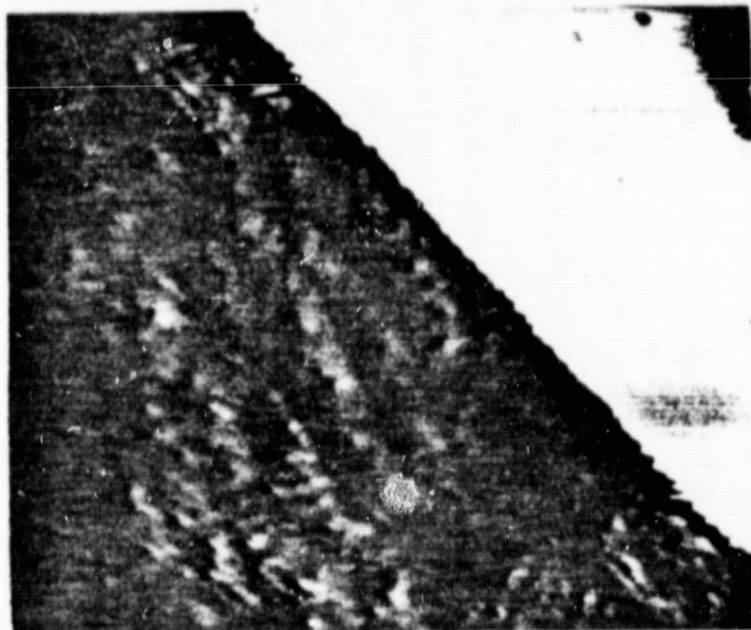
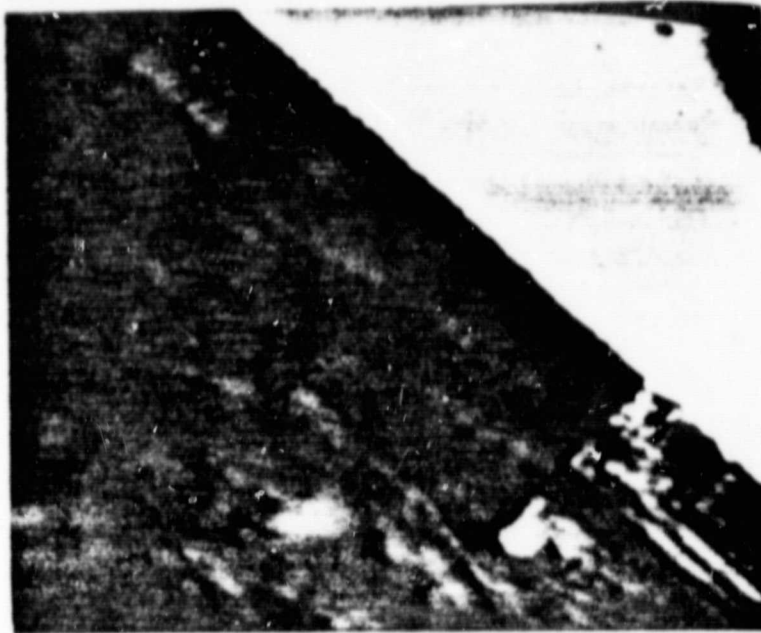


S-2 - Acoustic amplitude micrographs taken on areas (a) top and (b) bottom of solar cell S-2. Both areas contain much texture, although the weld area of (a) appears more attenuating than the cell itself.

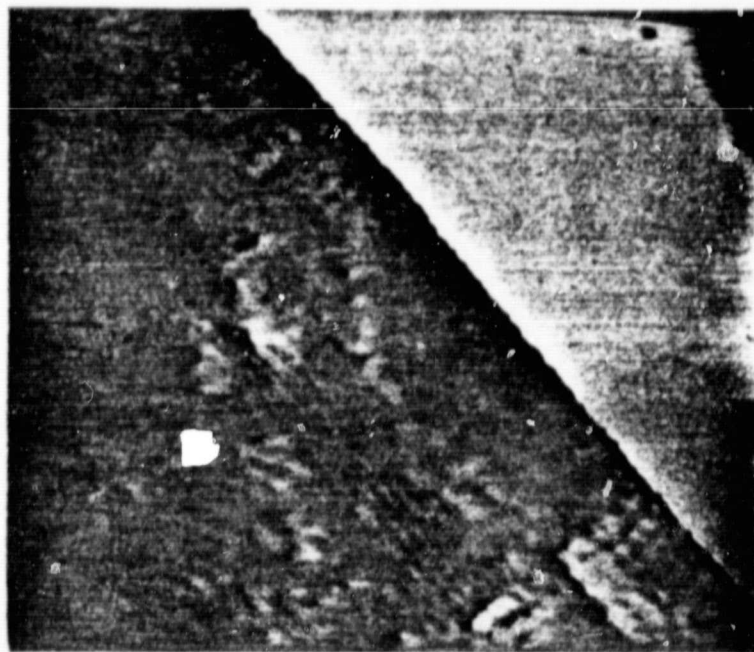
ORIGINAL PAGE IS  
OF POOR QUALITY



S-3 - Acoustic amplitude micrographs from solar cell S-3. The top was taken from area (a) and the bottom area (b). Both have a considerable amount of structure. The (b) area is outlined due to its low visibility. (b) is more attenuating than area (a).

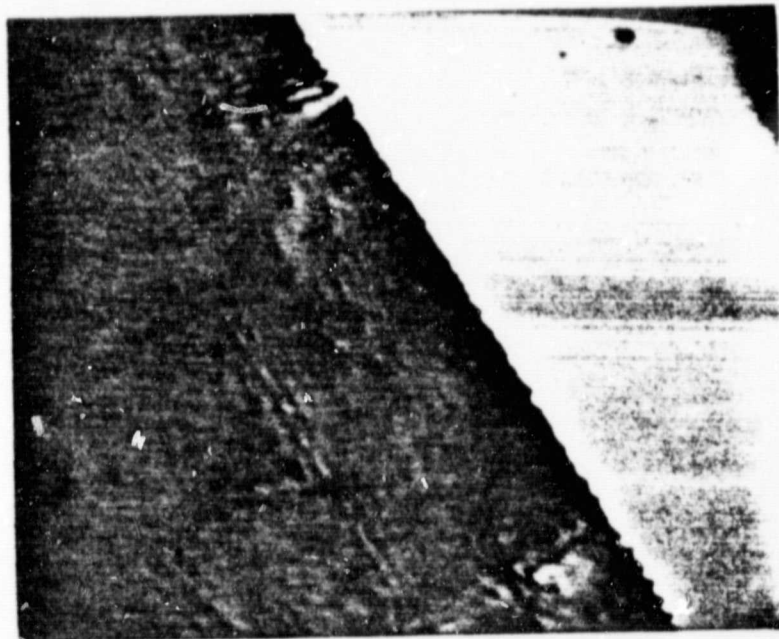
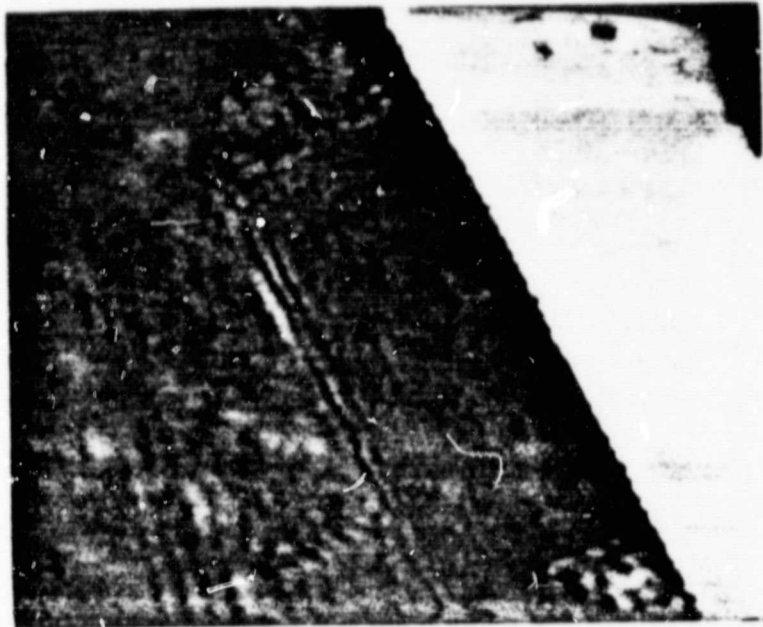


S-4 - Acoustic amplitude micrographs taken on sample S-4. The top micrograph was taken in area (a) and the bottom in area (b). Both contain a considerable amount of structure.



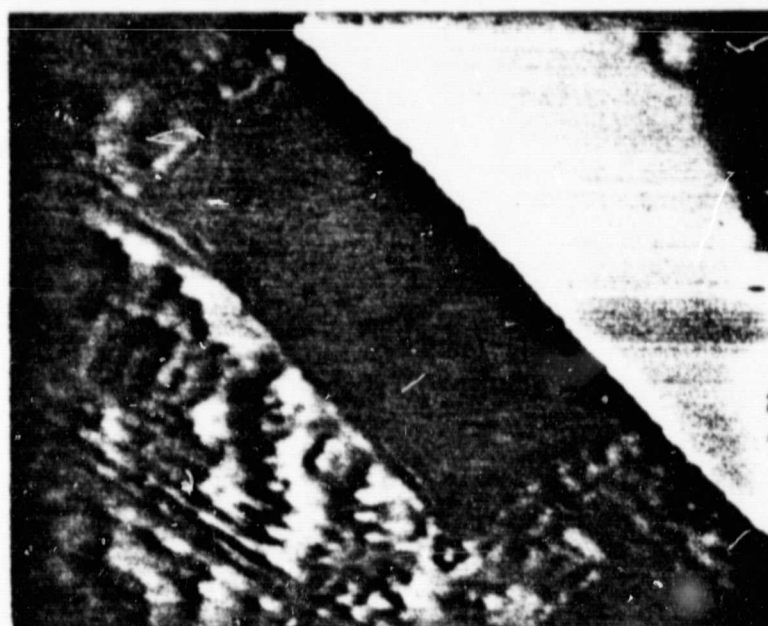
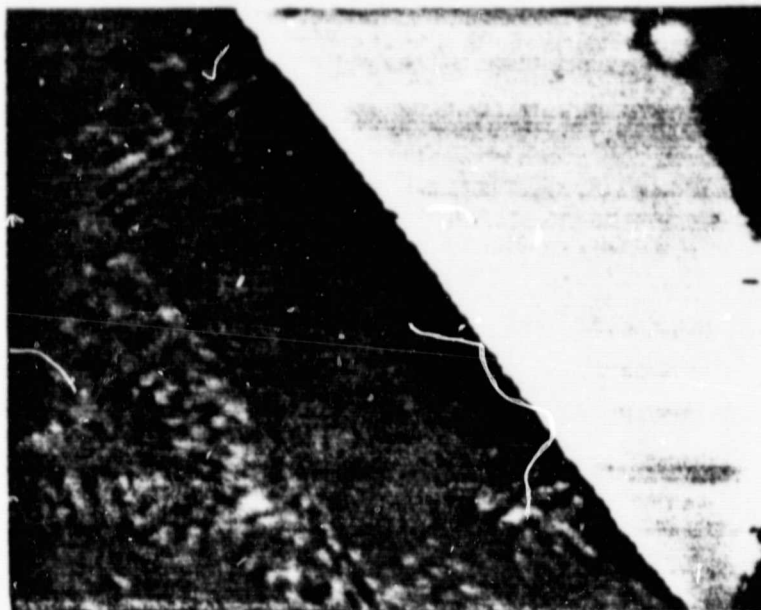
S-5 - Two acoustic amplitude micrographs both taken on solar cell S-5. The top micrograph was taken in area (a) and the bottom from area (b). Two delaminated regions are very apparent in the area (a). Area (b) has considerable structure.





ORIGINAL PAGE IS  
OF POOR QUALITY

S-6 - Amplitude acoustic micrographs taken on solar cell S-6. The top micrograph taken in area 1 and contains much structure. It is also more attenuating than the cell. The bottom micrograph taken on area (b) and also shows considerable structure.



S-7 - Amplitude acoustic micrograph taken on sample S-7. Both areas a and b (top and bottom) show extreme attenuation compared to the solar cell. These areas are considered the worst of the "S" group of cells.

## PHASE II

Micrographs in this section were taken on the cells labeled A-. A total of eleven samples were evaluated in this section A-5, 6, 8, 12, 13, 14, 20, 22, 23, 24 and A-7. A-7 has two tabs, each welded in three places on the body of the cell.

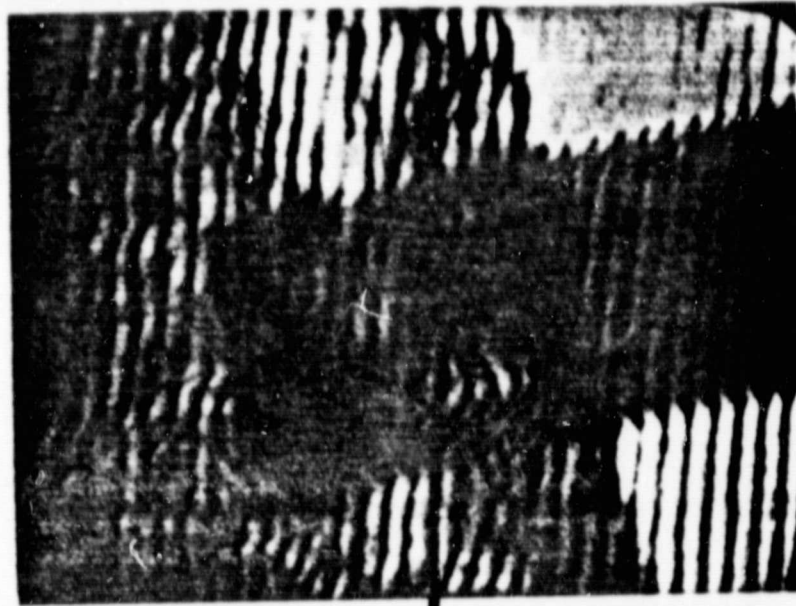
### SUMMARY OF RESULTS

<u>Cell</u>	<u>Area</u>	<u>Description</u>
A-5	a	little acoustic transmission
	b	narrow band of transmission
A-6	a	both similar, two small
	b	areas of good transmission
A-8	a	both have many small
	b	areas of good transmission
A-12	a	several areas good transmission
	b	small area transmission
A-13	a	large area good transmission
	b	smaller area good transmission
A-14	a	similar weld area, a has
	b	better transmission
A-20	a	both weld areas similar
	b	a is slightly larger than b
A-22	a	large area good transmission
	b	no tab on pad
A-23	a	large area good transmission
	b	little transmission in weld area
A-24	a	each has two areas of
	b	transmission with a being larger

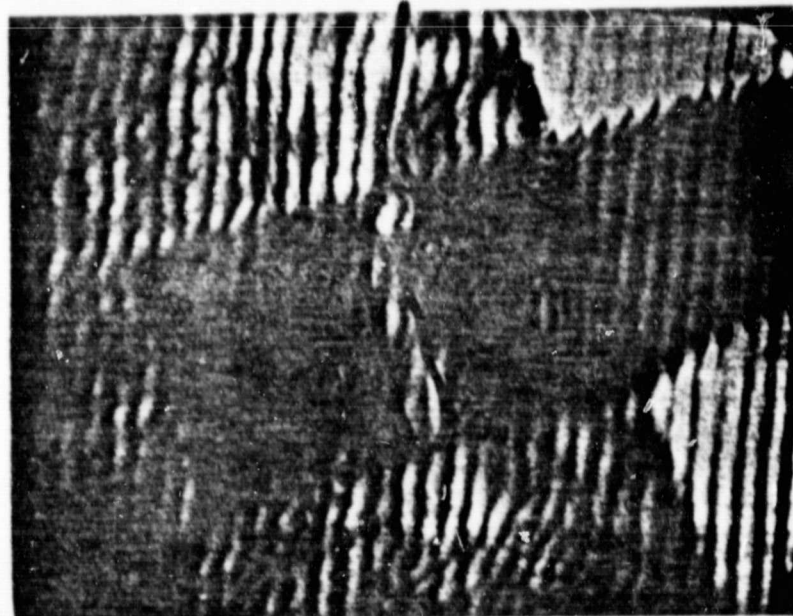
Overall, comparing the "A" group with the "S" group, the pad areas have better transmission and the weld area consistently from tab a to b is much better.

A-7 (See Sketch accompanying micrographs.)

The tab on the left exhibited three very small well defined weld areas while the tab on the right had very nondistinct areas of weld contact.

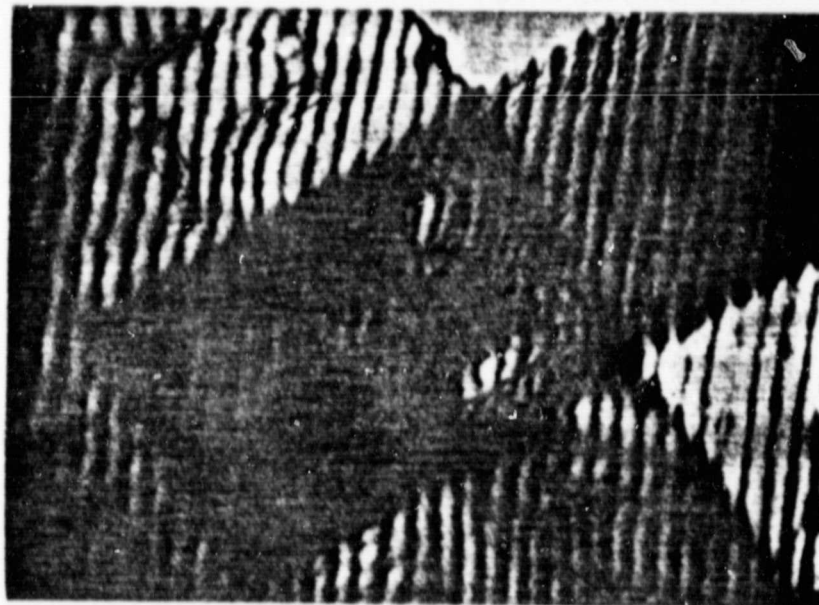
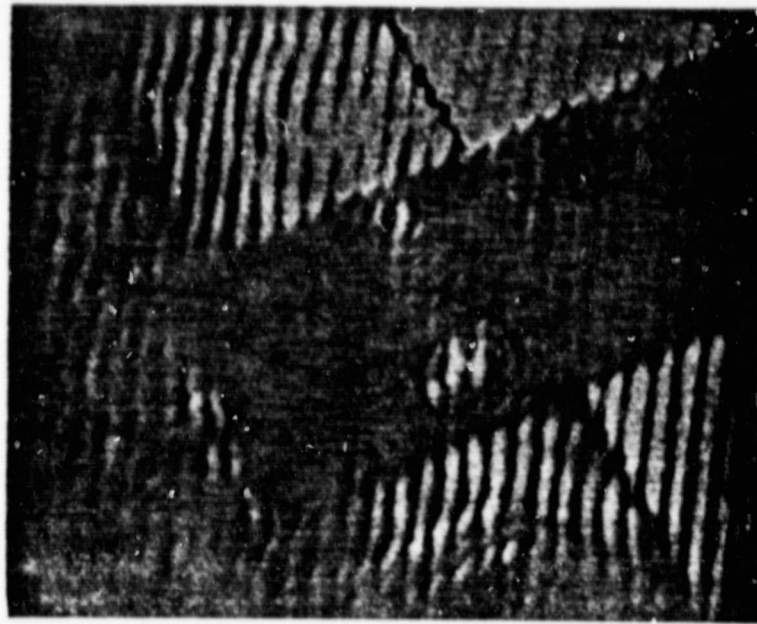


TRANSMISSION



ORIGINAL PAGE IS  
OF POOR QUALITY

- A-5. These acoustic micrographs were taken in the acoustic interferogram mode. Tab a is shown in the top micrograph. Very little acoustic transmission occurs (area of straight coherent fringes). In the lower micrograph tab b has a narrow band of good transmission although the size of area is not very great.

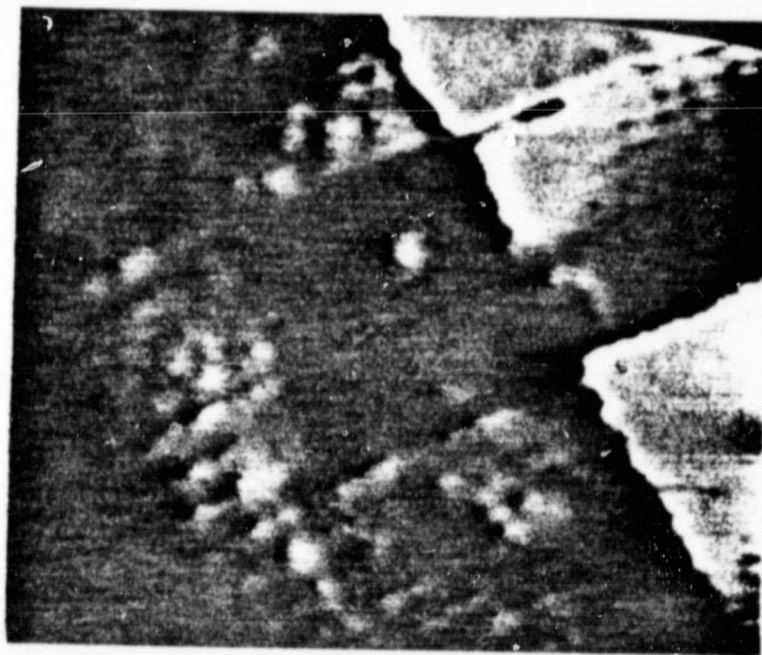


A-6. Both tab a (top) and b (bottom) were taken in the interferogram mode and appear very similar. Two small areas of good transmission occur for each weld area.





A-8. Both of the acoustic amplitude micrographs shown here exhibit many small areas of good transmission. The top was taken on a, the bottom on b.



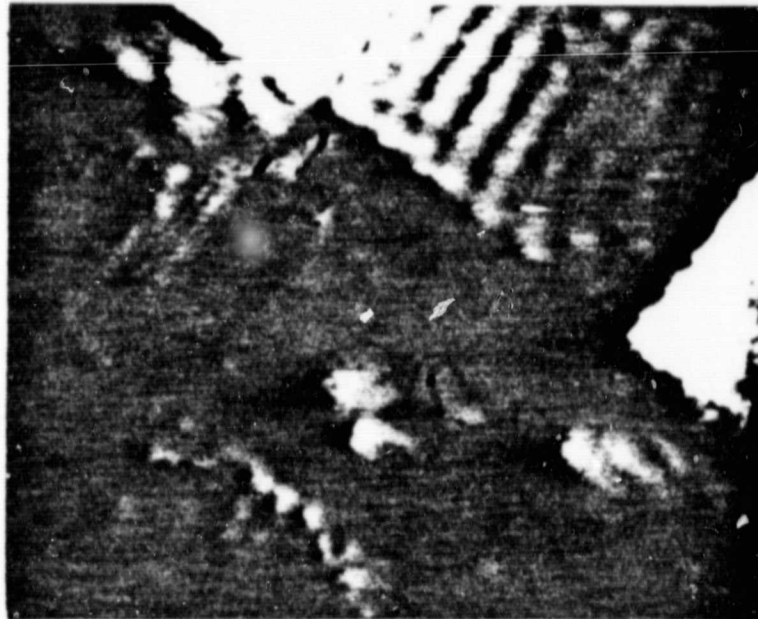
ORIGINAL PAGE IS  
OF POOR QUALITY

A-12. The top micrograph (tab a) shows several small areas having good acoustic transmission while in the bottom micrograph fewer areas are found (tab b).

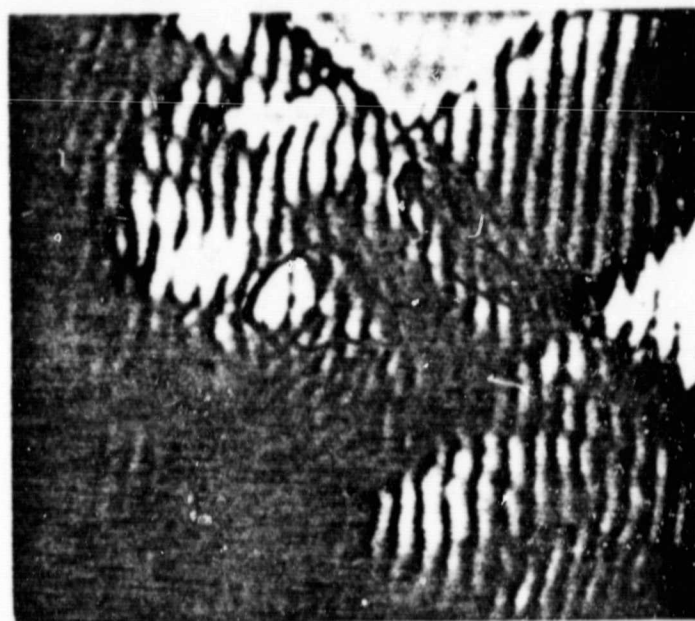




M<sub>0</sub>

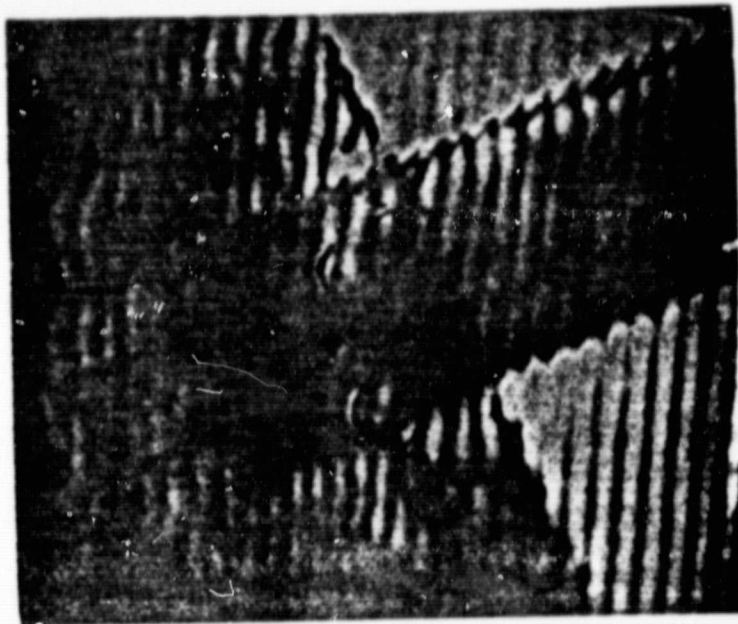


A-13. Top micrograph (tab a) illustrates a fairly large area having good acoustic transmission, while the bottom micrograph (tab b) has a smaller area but exhibits good transmission.

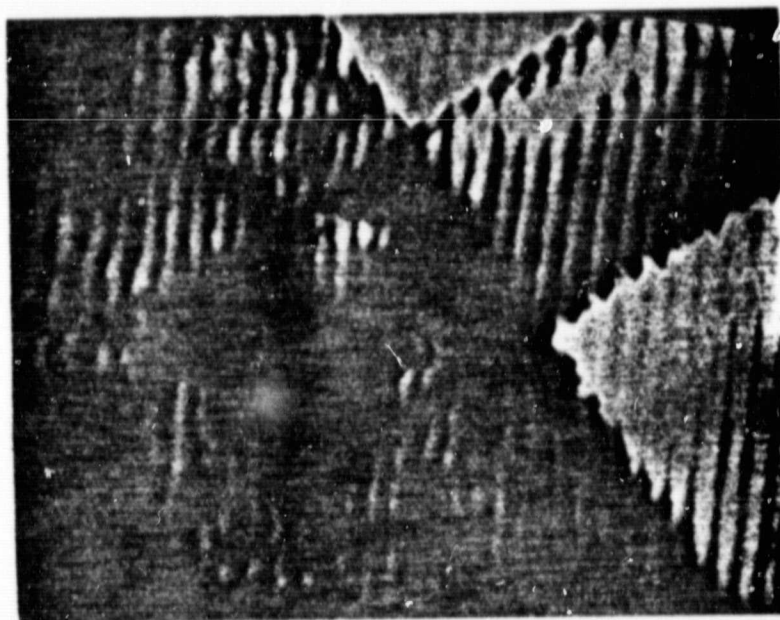


ORIGINAL PAGE IS  
OF POOR QUALITY

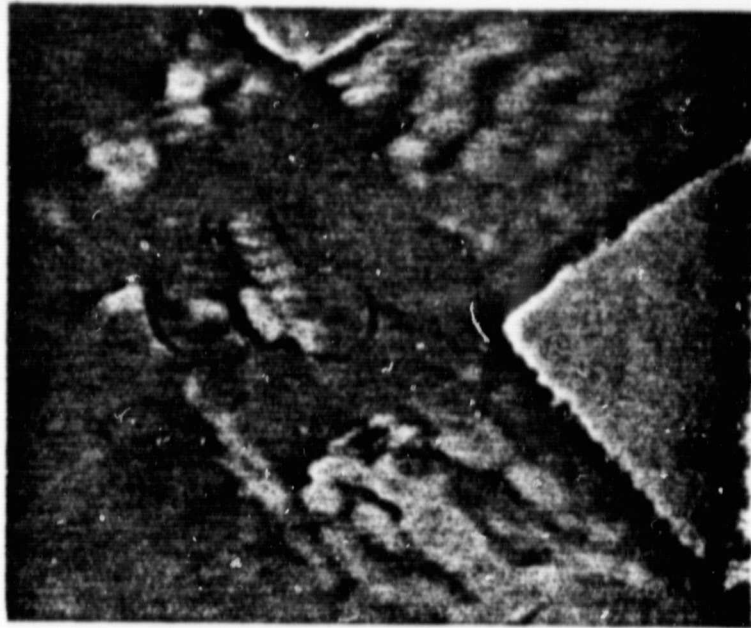
A-14. Both the top (tab a) and bottom (tab b) micrographs have very similar patterns produced in the weld area. While tab a has much better acoustic transmission than b.



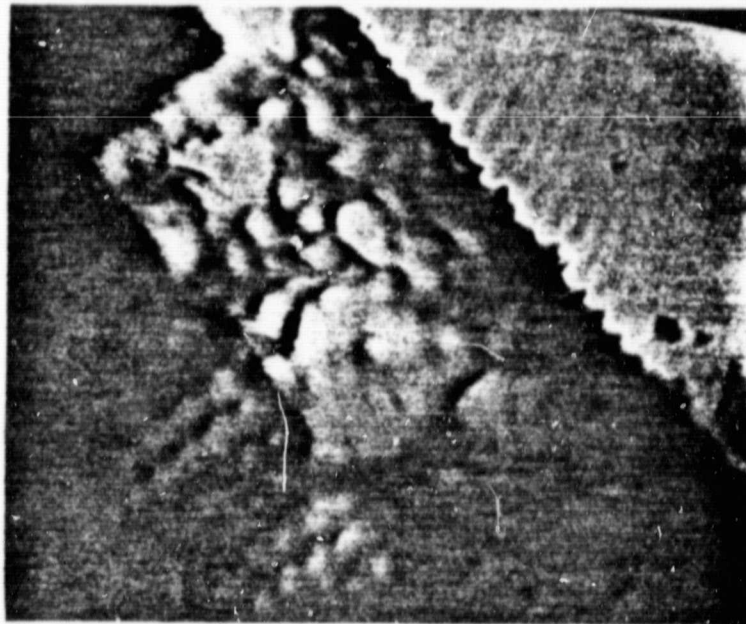
balanced  
tip pressure



A-20. Both tab a (top) and b (bottom) exhibit similar shaped weld areas although a has slightly larger area of good acoustic transmission.

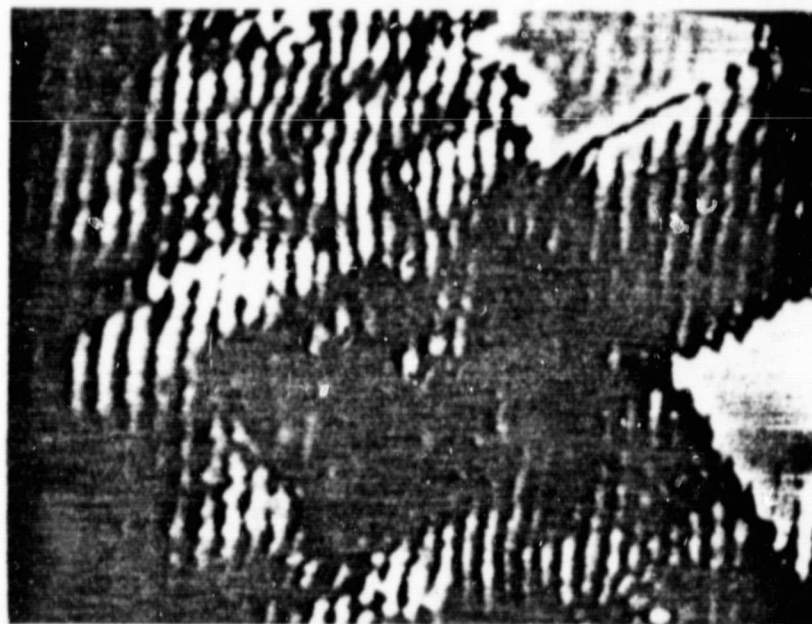


M<sub>0</sub>

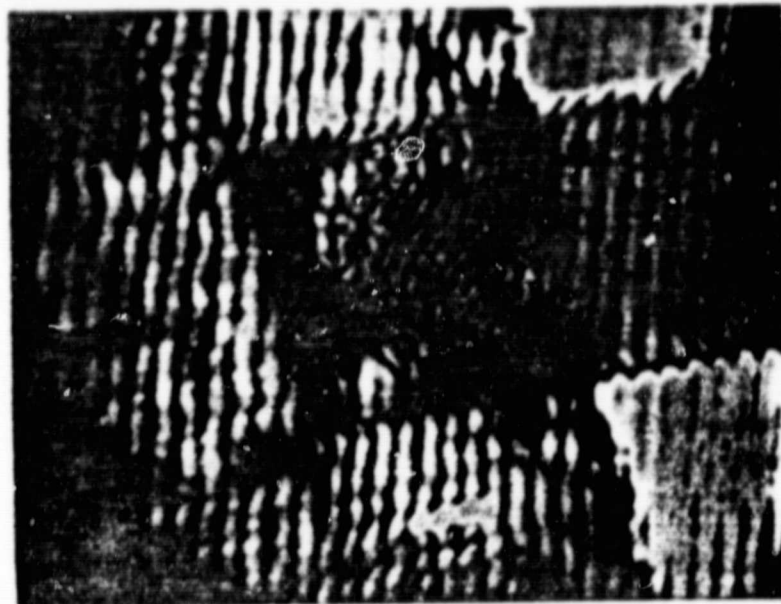


A-22. This cell was received with only one tab in the 'a' position on the solar cell (top). It appears to have a large weld area having good acoustic transmission. The remaining pad shown here in the bottom micrograph exhibits considerable structure.





A-23. The top micrograph illustrates the "a" region having good transmission acoustically and fairly large size. The "b" region (lower micrograph) has very little acoustic transmission in the area.



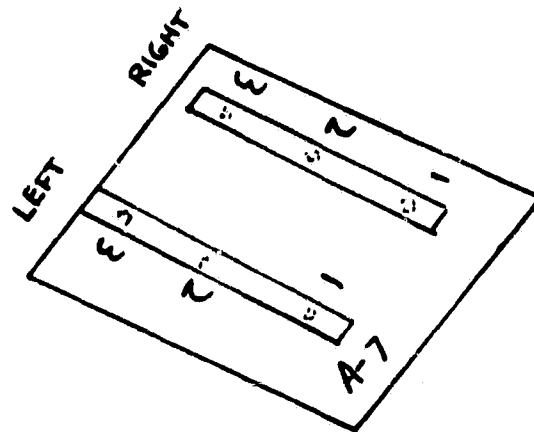
2 mil electrode  
spacing

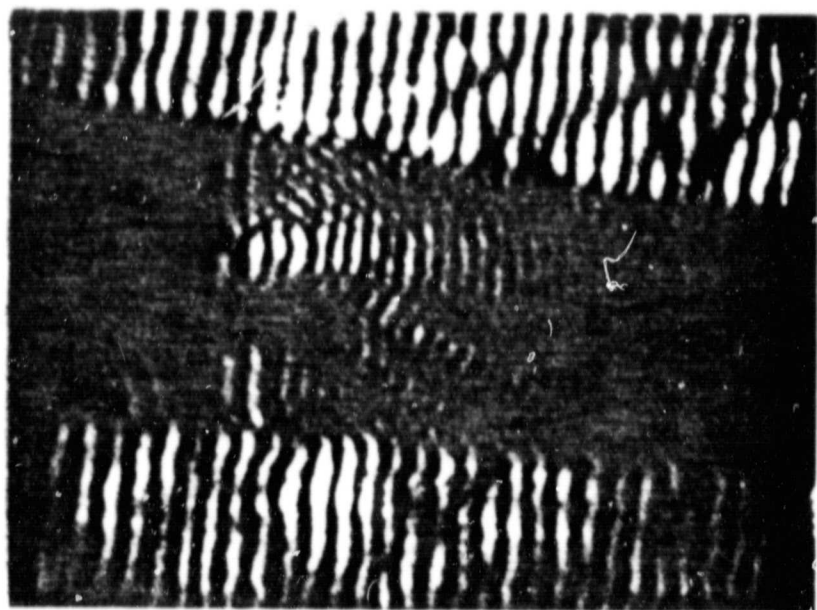


A-24. Both tab a (top) and b (bottom) appear very similar according to the shape of the weld area. "A" having slightly more surface contact than "b". The placement of tab b appears to extend further into the cell than a.

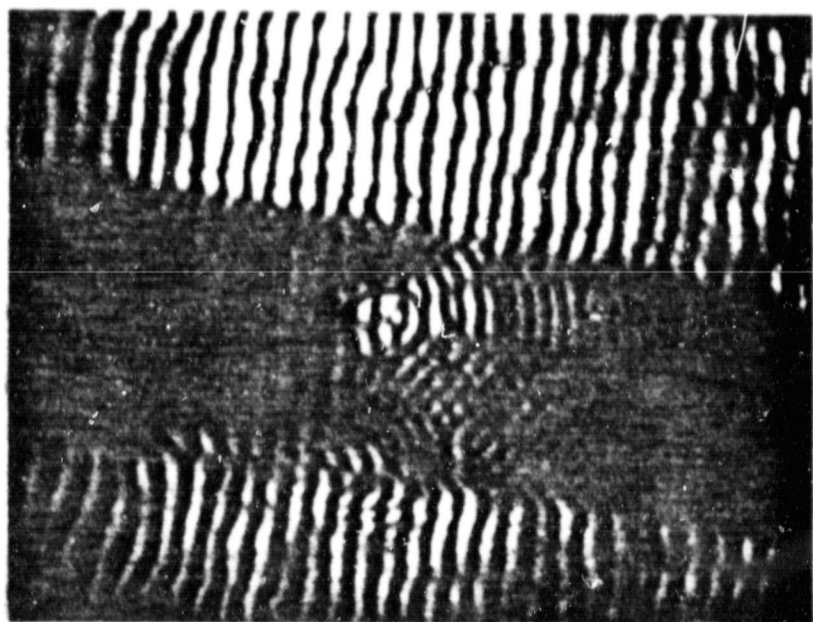
ORIGINAL PAGE IS  
OF POOR QUALITY

The following micrographs were taken on sample A-7. Two tabs were welded, each in three places on the cell. A sketch is shown for comparing the micrographs to the area of the sample from which it was taken. The tab on the left exhibited three very small well defined weld areas while the tab on the right had very nondistinct areas of weld contact.

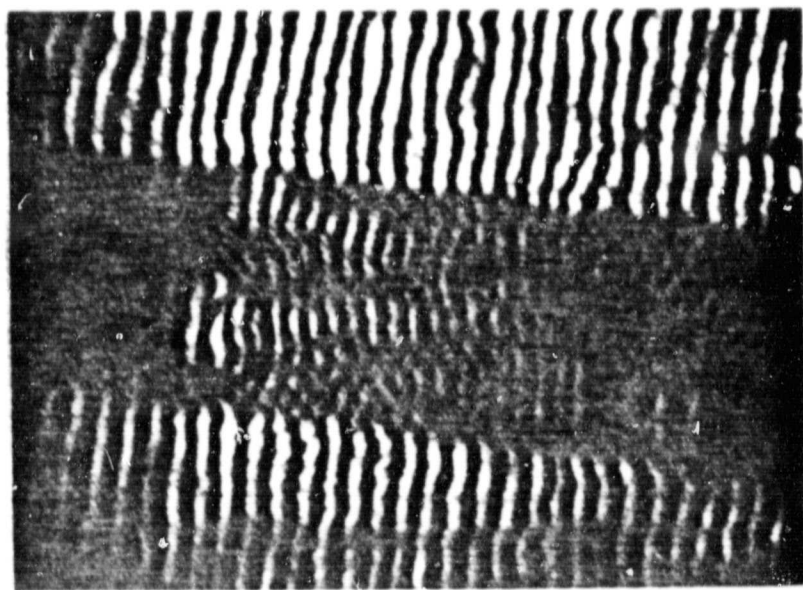




1L



2L

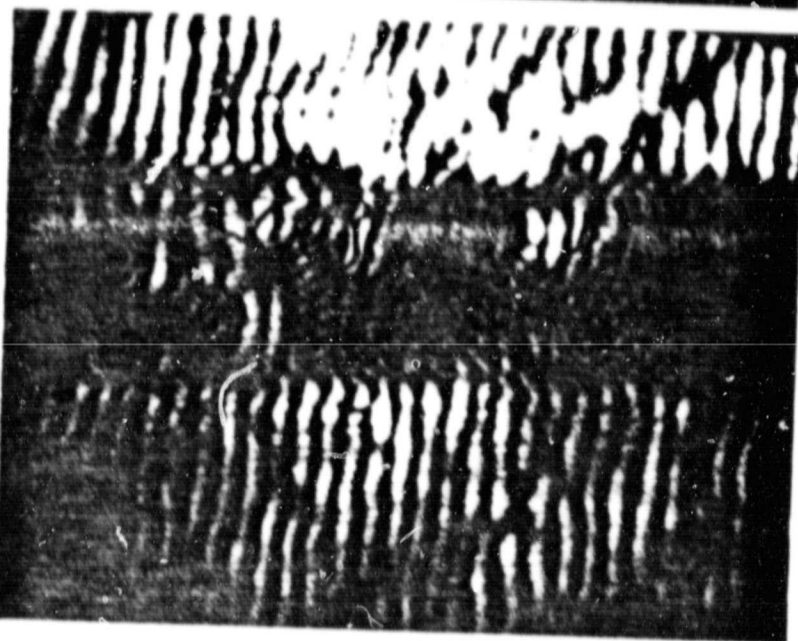


3L

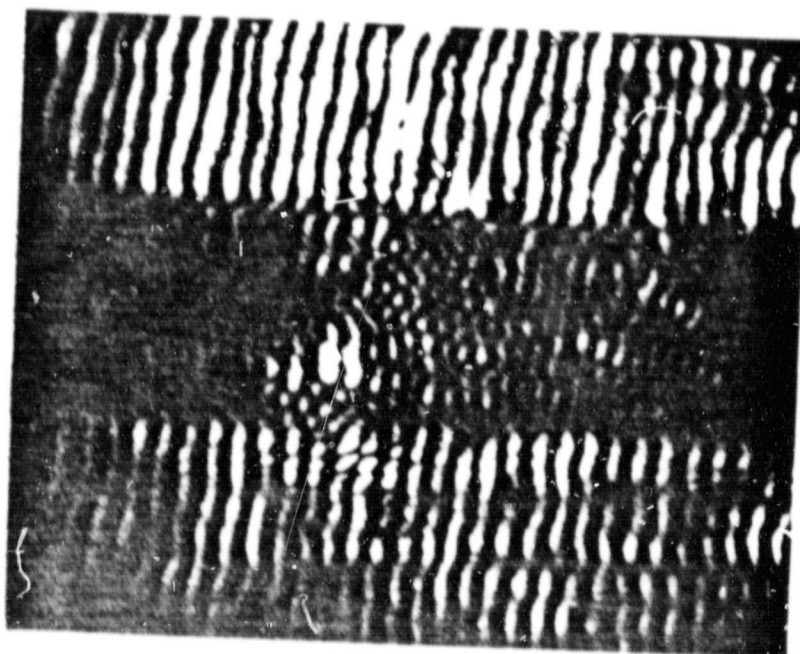




1R



2R



3R

### PHASE III

Evaluation of 16, 2 mil solar cells each containing 2 welded tabs.  
Each labeled S-.

The sample numbers were:

S-9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20, 21, 22, 24, 25  
and 30.

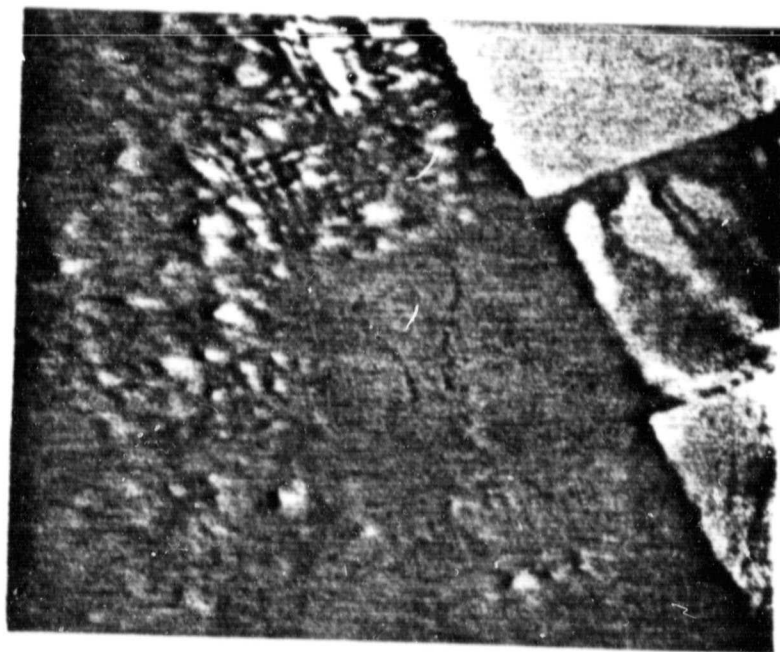
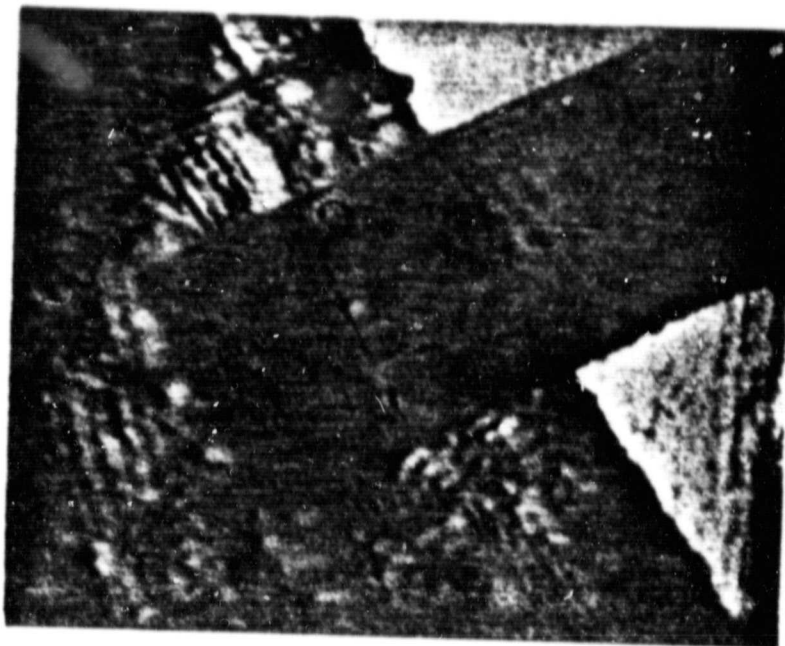
The handling procedure followed was the same as in Phase I. The two weld areas on each cell were examined and data was taken in the form of acoustic micrographs which follow:

#### SUMMARY OF RESULTS

<u>Cell</u>	<u>Area</u>	<u>Description</u>
S-9	a	weld area fairly poor transmission
	b	transmission fairly poor in weld
S-10	a	two circular areas with fair transmission
	b	weld area very small, transmission poor
S-11	a	large area of contact with good transmission
	b	poor transmission, small area of contact
S-12	a	poor acoustic transmission
	b	some fair transmission
S-13	a	small area of contact, fair transmission
	b	small area of contact, fair transmission
S-14	a	two areas fairly good transmission
	b	similar to (a) but slightly worse transmission
S-15	a	some fair transmission
	b	poor transmission
S-17	a	two areas with good transmission
	b	one large area with excellent transmission

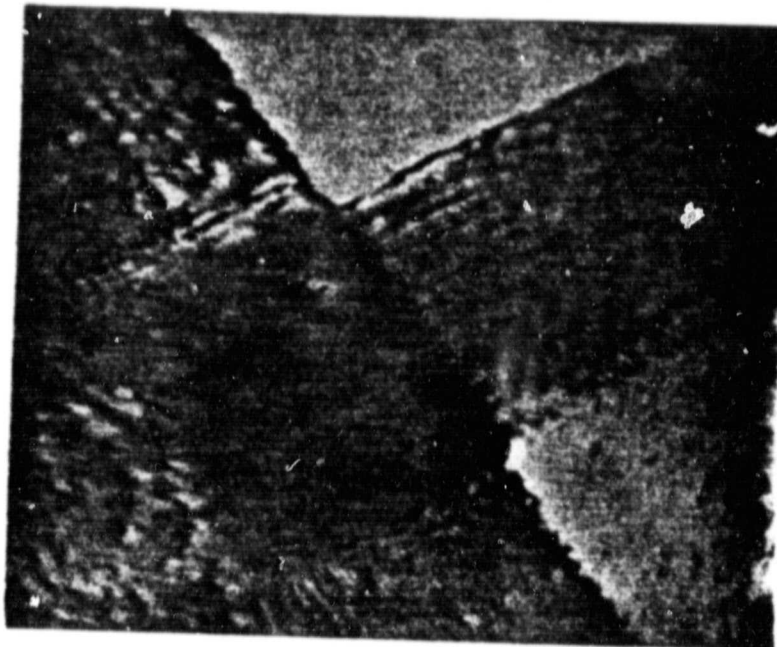
# SUMMARY OF RESULTS

<u>Cell</u>	<u>Area</u>	<u>Description</u>
S-18	a	three small areas with good transmission
	b	two small areas with fair transmission
S-19	a	one large area, good transmission
	b	large area with fair transmission
S-20	a	large area, good transmission
	b	very good transmission, large area
S-21	a	three areas fair transmission
	b	poor transmission and possible crack
S-22	a	two areas with poor transmission
	b	very poor overall transmission
S-24	a	large area, poor transmission
	b	large area, fairly good transmission
S-25	a	two small areas of good transmission
	b	two areas poor transmission
S-30	a	very good transmission
	b	very good transmission

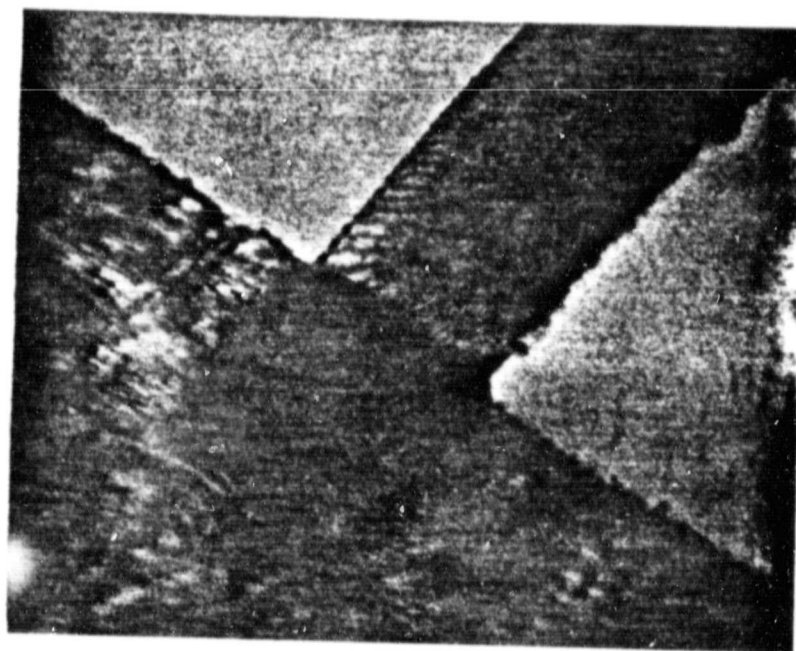


- S-9. These two amplitude acoustic micrographs were taken on the weld area of tab a (top) and tab b (bottom) on cell S-9. The pad area exhibits much structure and the weld area appears fairly small. Both a and b are similar to each other.

ORIGINAL PAGE IS  
OF POOR QUALITY

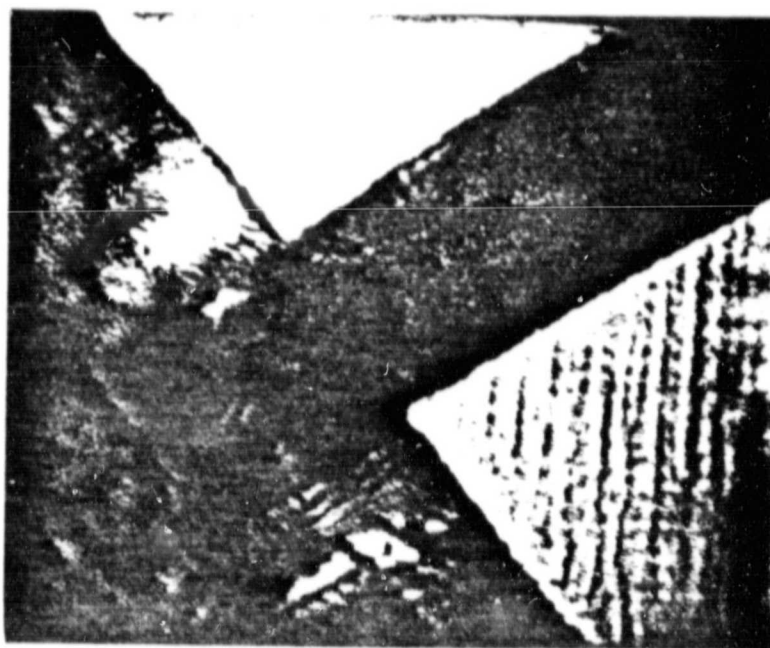
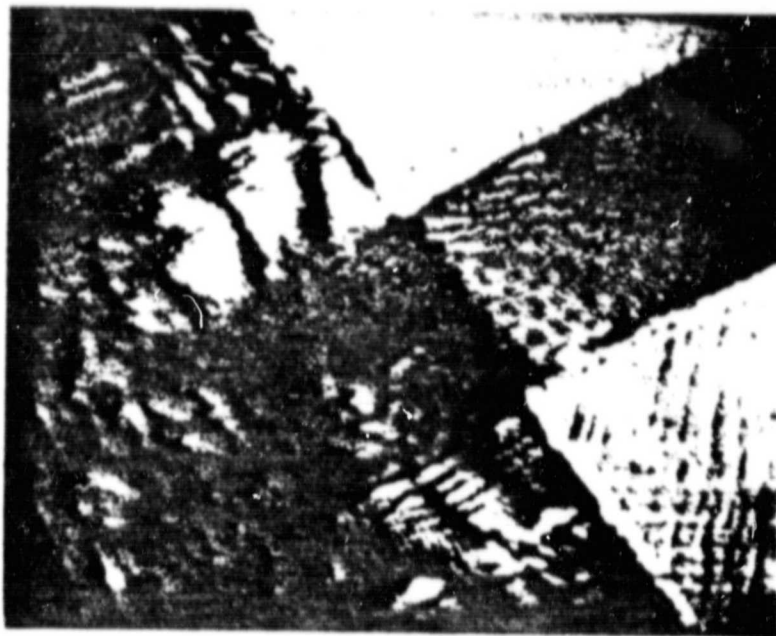


.015" spacing

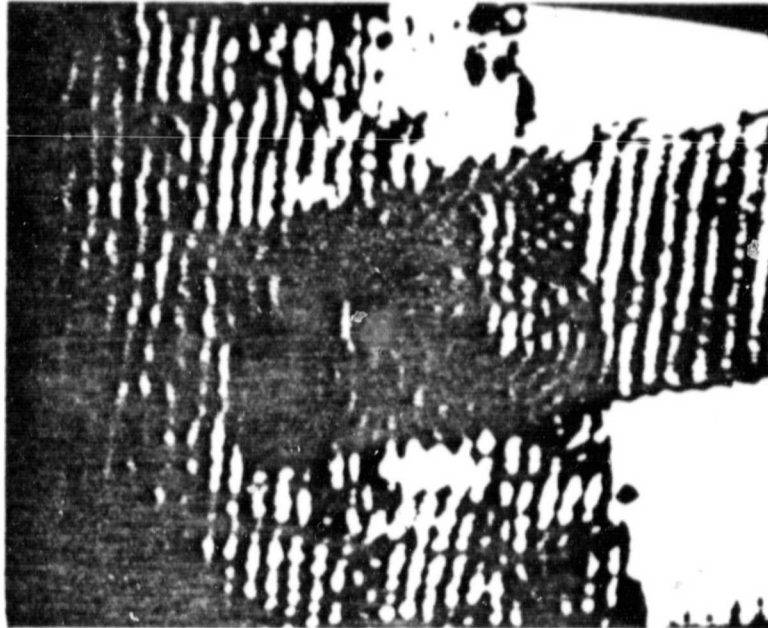
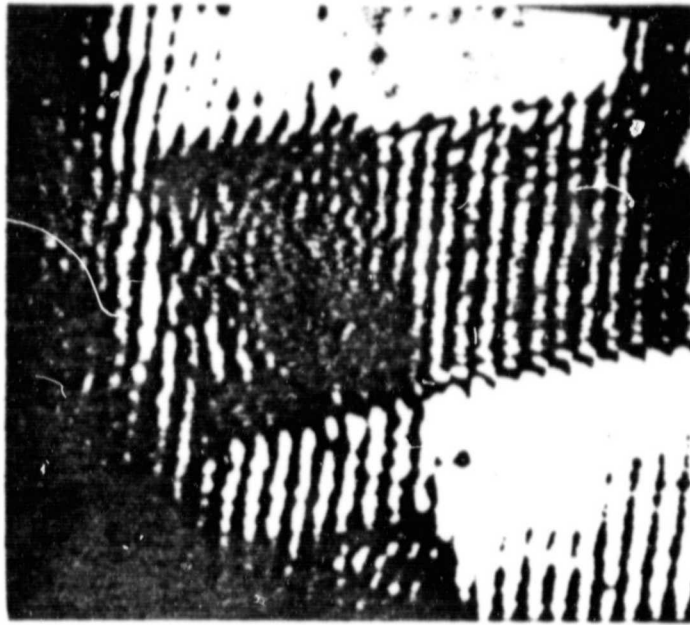


ORIGINAL PAGE IS  
OF POOR QUALITY

S-10. The top micrograph taken on tab a and the bottom tab b appear to have two very small weld areas. The acoustic transmission is also very poor.

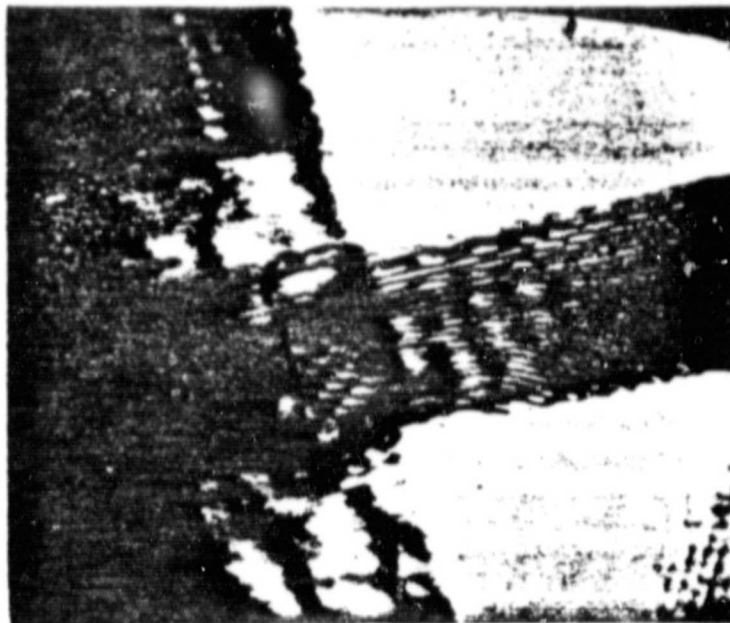


S-11 The top micrograph taken on tab a exhibits fairly good transmission over a rather large area of contact. The lower micrograph (tab b) does not have a very well defined area of transmission.

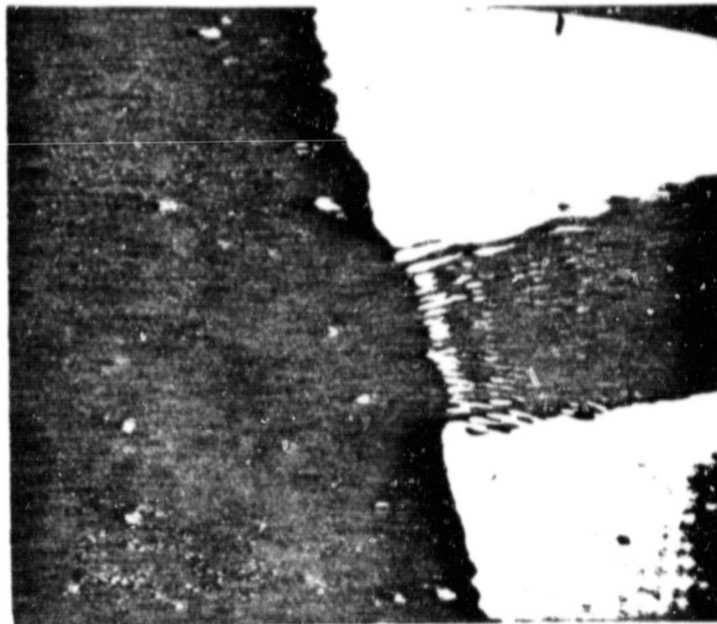


S-12. Neither tab a or b appears to have very good acoustic transmission in the weld area. Both pads have much better transmission than has normally been found in cells of this group. Tab b extends further into the sample than a and has an area with some transmission although the interference fringes are squiggled.

ORIGINAL PAGE IS  
OF POOR QUALITY



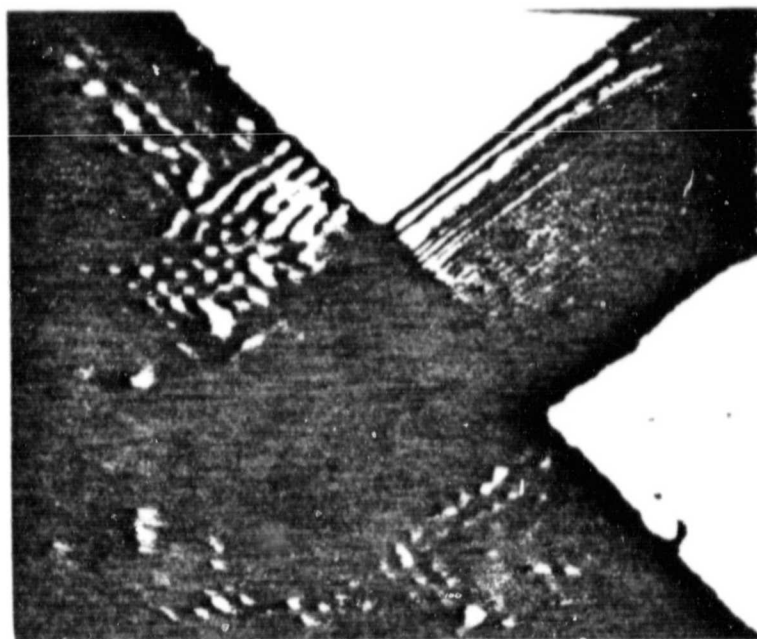
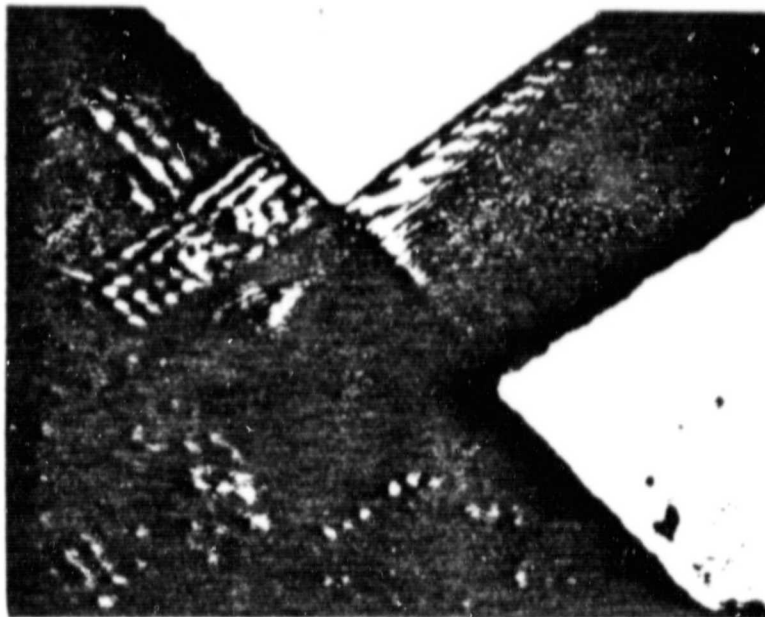
.002" spm



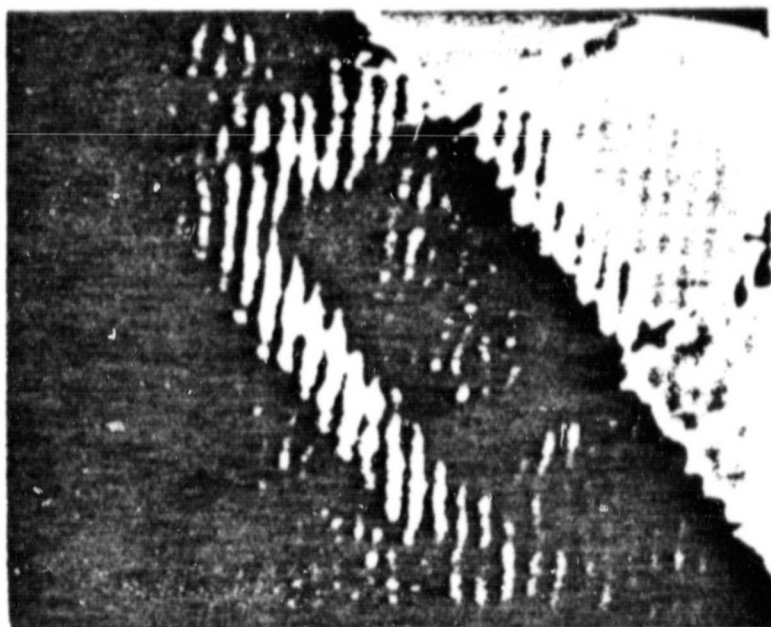
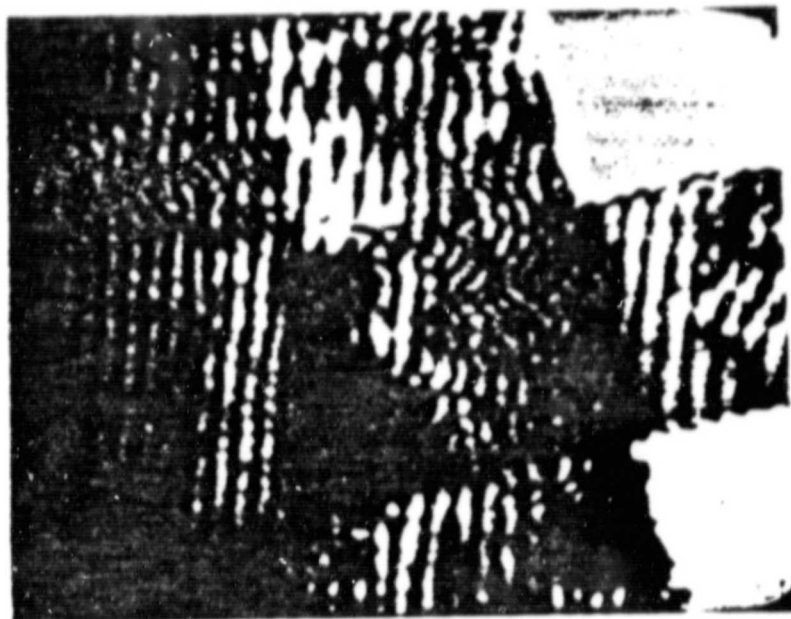
ORIGINAL PAGE IS  
OF POOR QUALITY

S-13. The top micrograph, tab a, exhibits much better transmission in the pad area and along the edges of the tab in the welded area than does b (bottom).



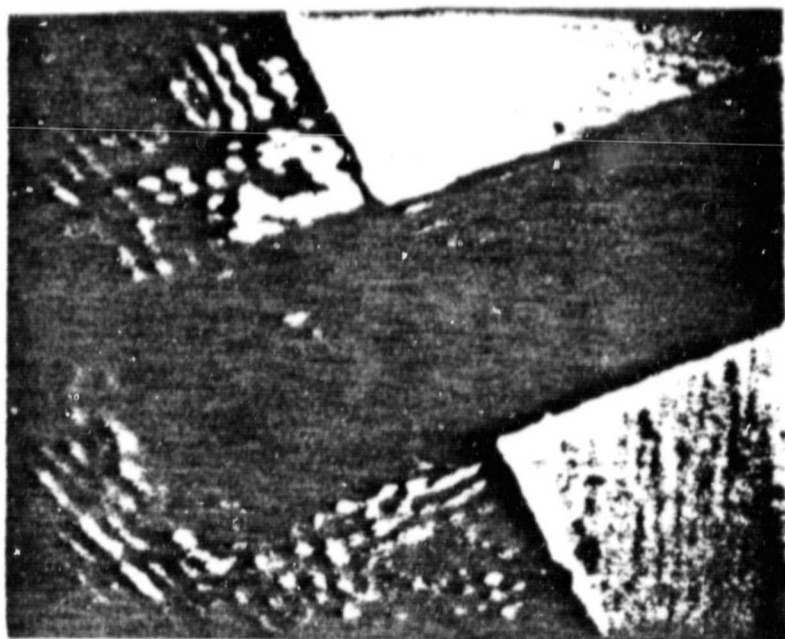
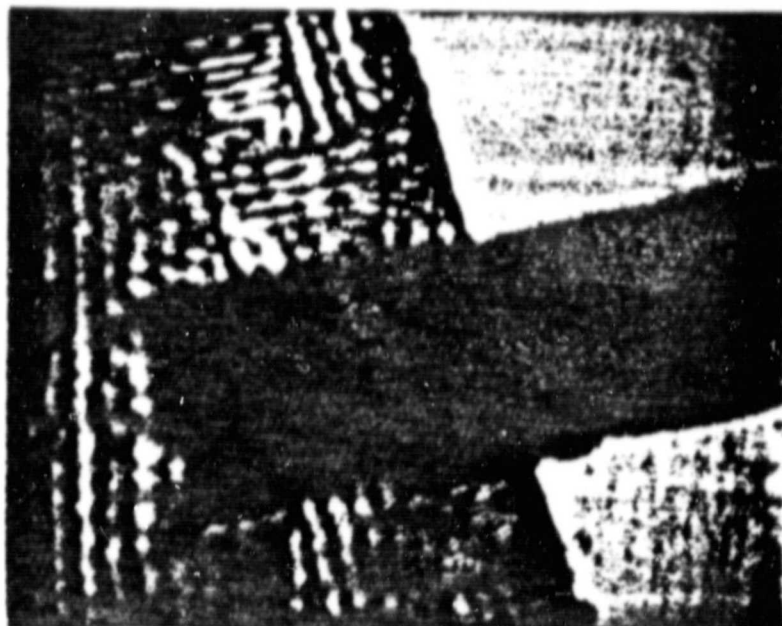


S-14. The overall structure of these pads appears more homogeneous than found in the other cells. Two large areas of contact are visible in tab a, while much less area is visible in tab b.

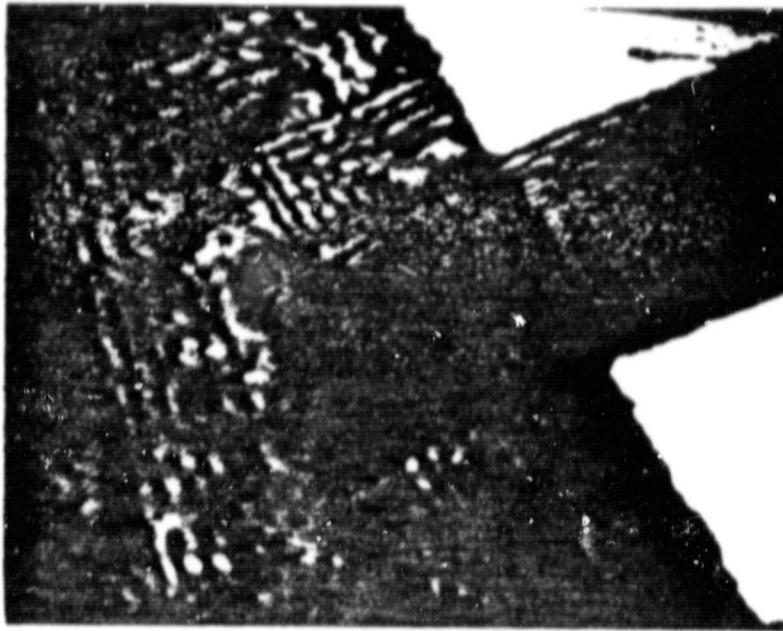


ORIGINAL PAGE IS  
OF POOR QUALITY

S-15. These micrographs illustrate the weld areas of both a and b tabs. While a (top) has only a very small area with some transmission, b (bottom) has relatively none.



S-17. The structure of these cells also appears very clean compared with others labeled "S". The area of contact in a (top) is rather small and is much larger in b (bottom).

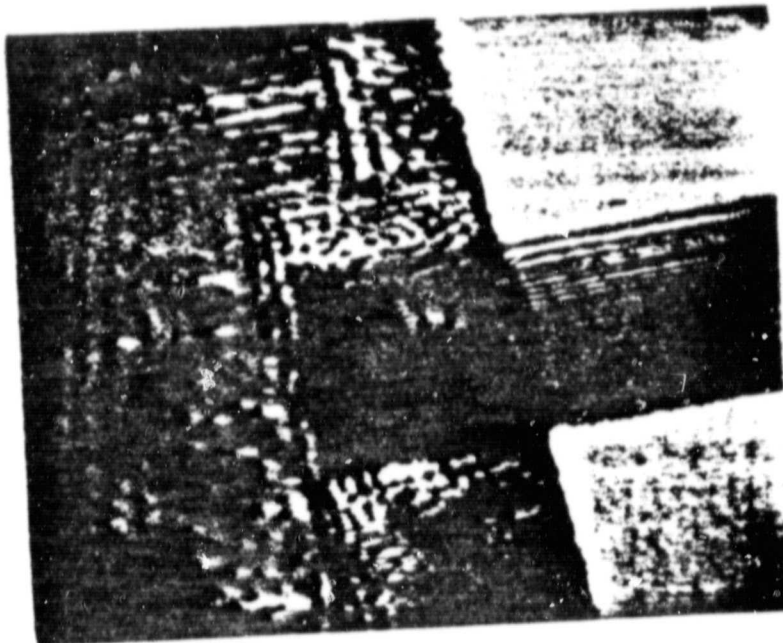


015 " spacing

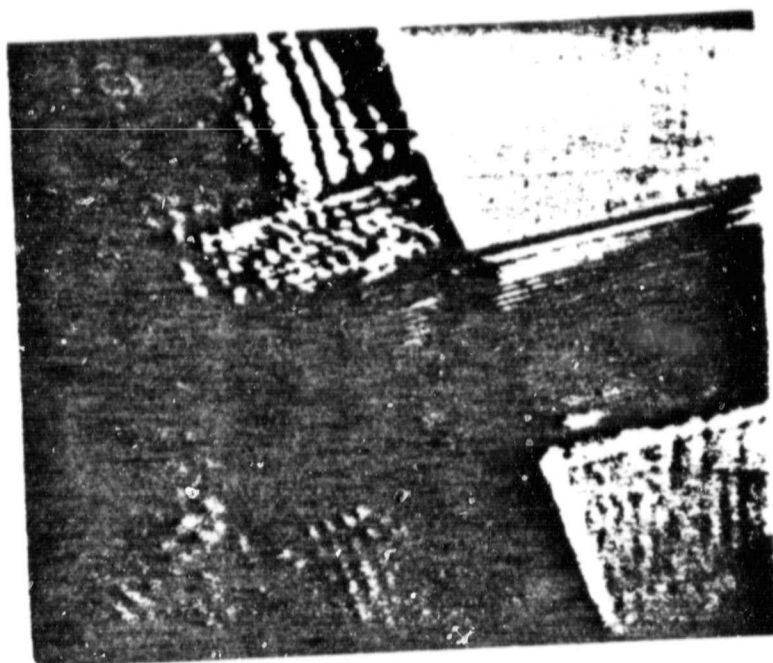


ORIGINAL PAGE IS  
OF POOR QUALITY

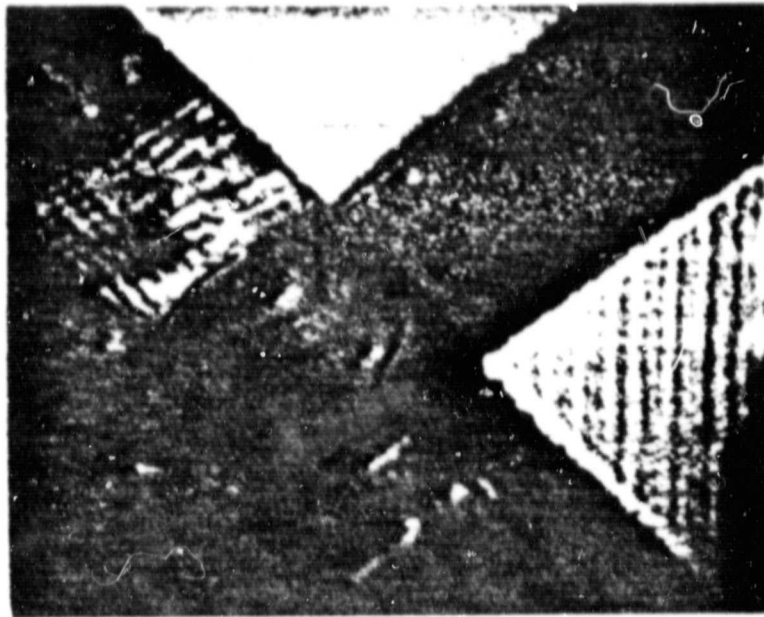
S-18. The top micrograph was taken on tab a where many small areas of contact are visible. In b, two larger areas are found near the edge of the tab. There is much structure in the cell itself.



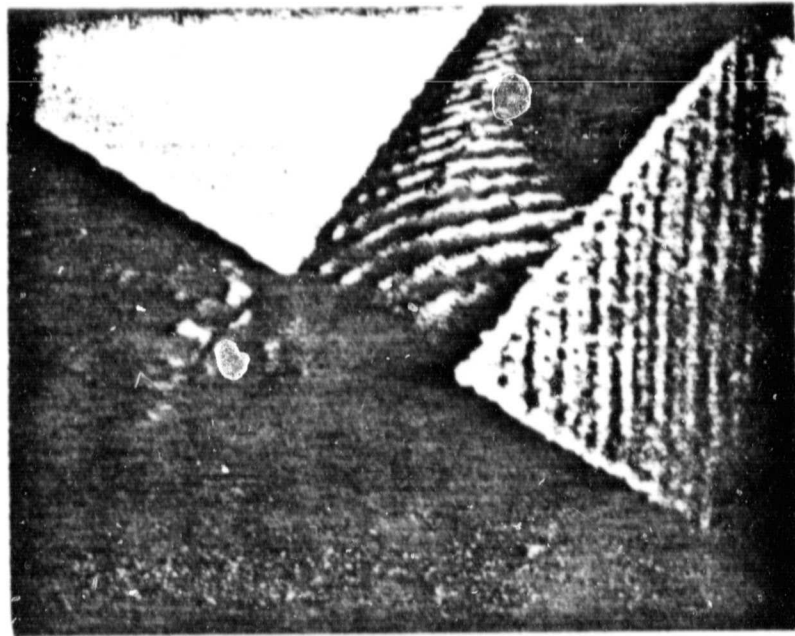
.002" spacing



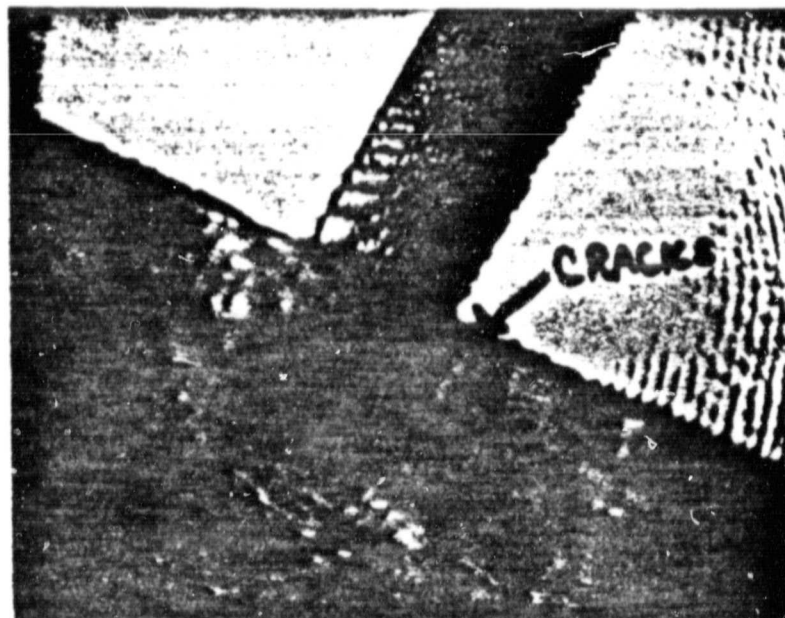
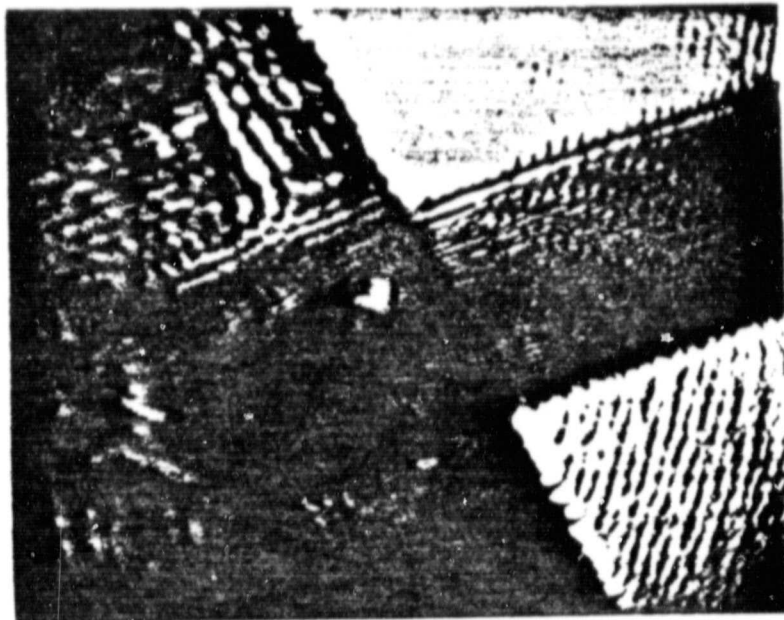
S-19. In the top micrograph taken on tab a, a large area of contact is found. In the lower micrograph from tab b a very large area can be seen having good acoustic transmission.



$t = 300 \mu$



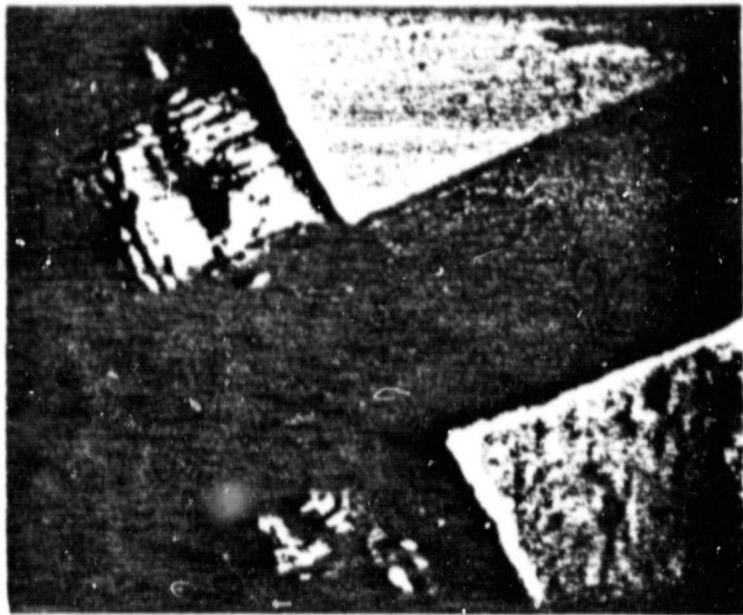
S-20. The top micrograph shows the a tab having an exceptionally large area of good acoustic transmission. The b tab (lower) also has a rather large area of contact.



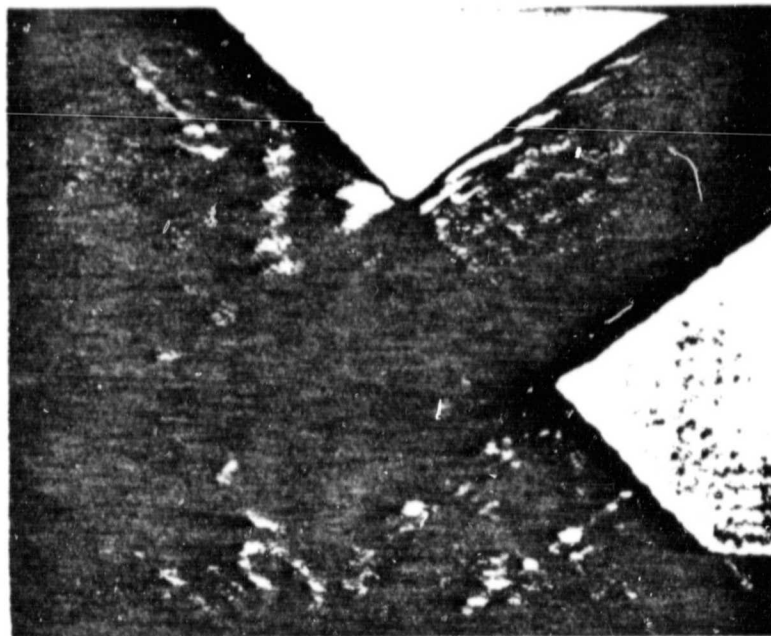
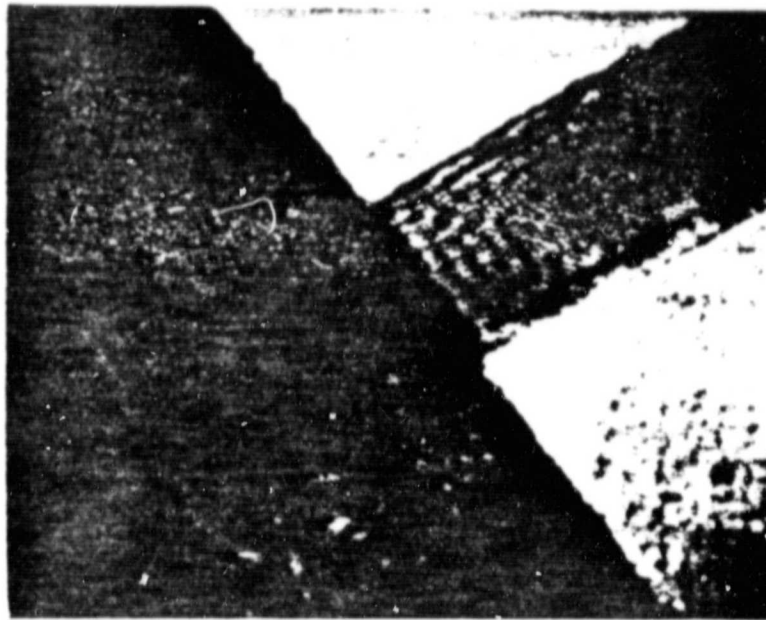
ORIGINAL PAGE IS  
OF POOR QUALITY

S-21. The tabs attached to this cell were different sizes as illustrated tab a (top) and tab b (bottom). A fairly large area of contact is found in a, while b is considerably smaller and more attenuating. A possible crack extends into the pad of b (circled).



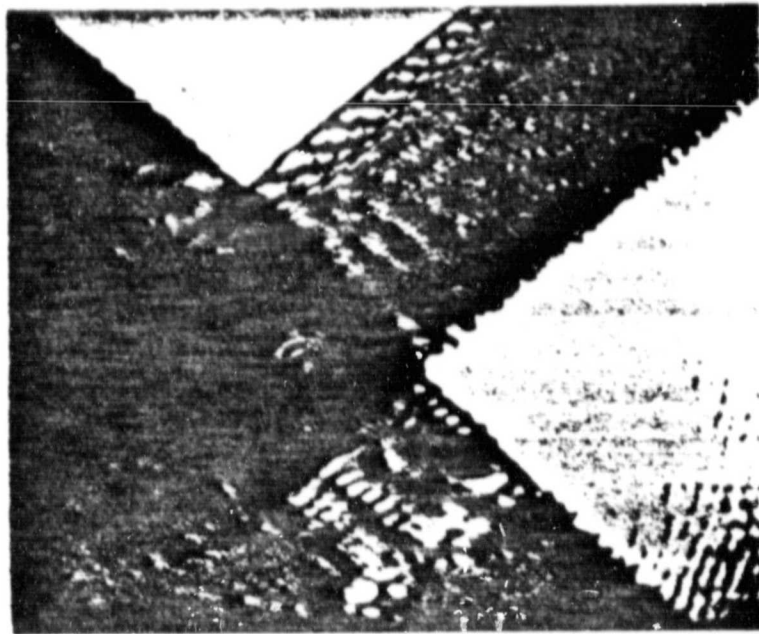
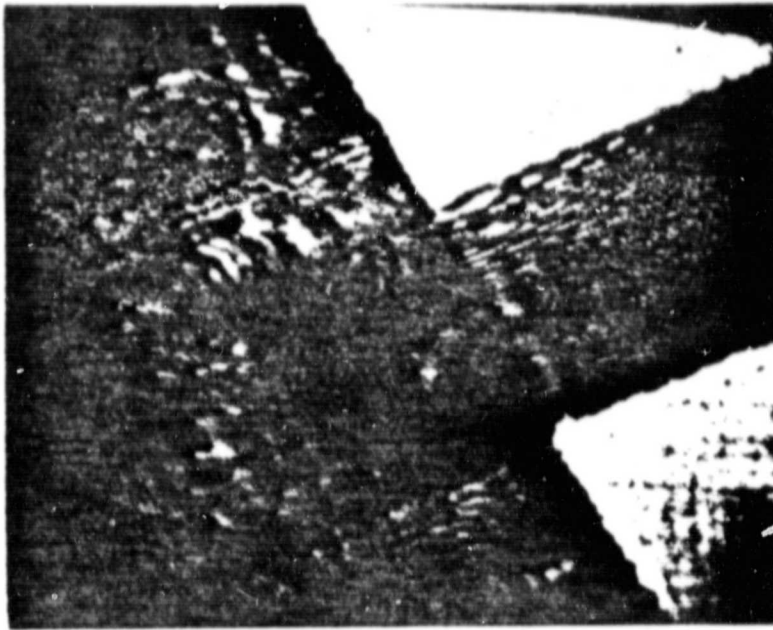


S-22. Two fairly large areas of contact are present in tab a (top) while almost no acoustic transmission is found in the weld area of tab b (bottom). The transmission is very poor in a, although a small amount of contact is assumed.

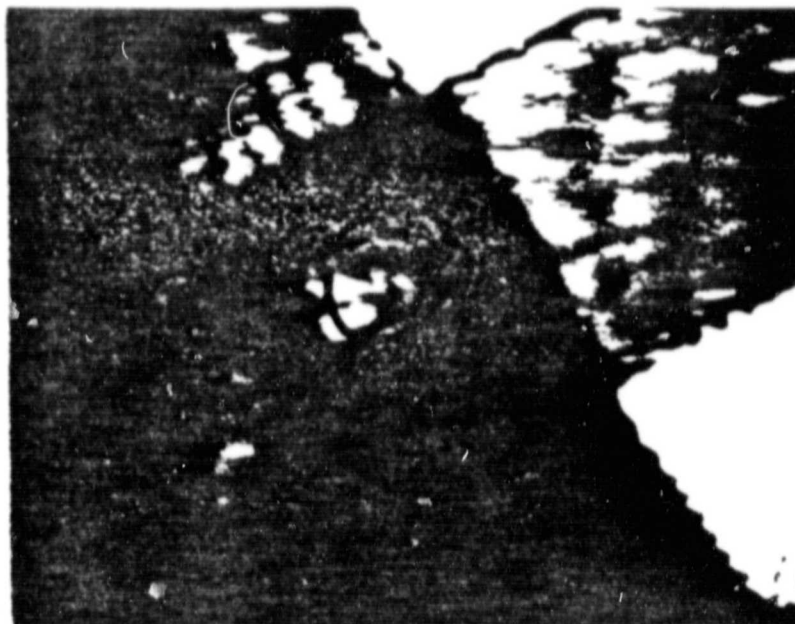


ORIGINAL PAGE IS  
OF POOR QUALITY

S-24. The top micrograph was taken on tab a which exhibits some acoustic transmission near the edge of the tab. The bottom micrograph taken on the b tab has a very large area of good transmission.



S-25. The top micrograph taken on tab a exhibits very small regions of contact and some acoustic transmission. Tab b (bottom) appears very similar to a.



Mo

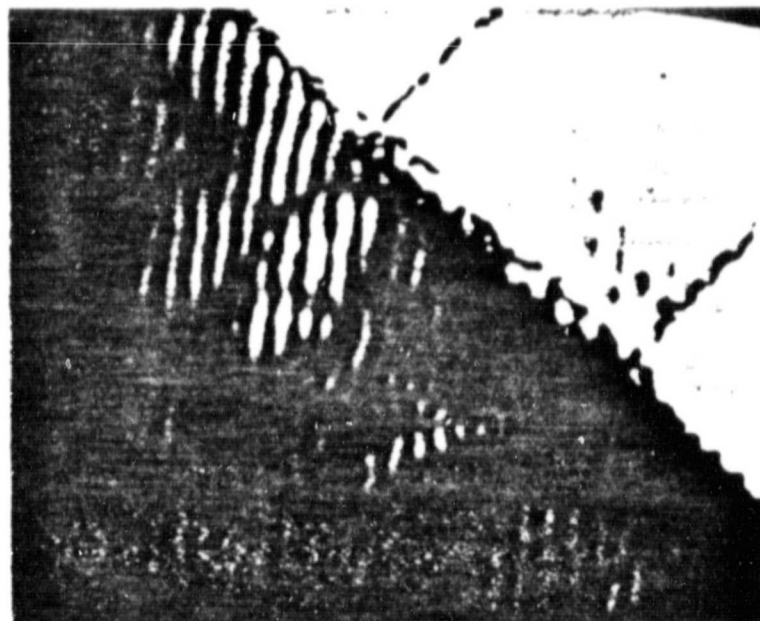
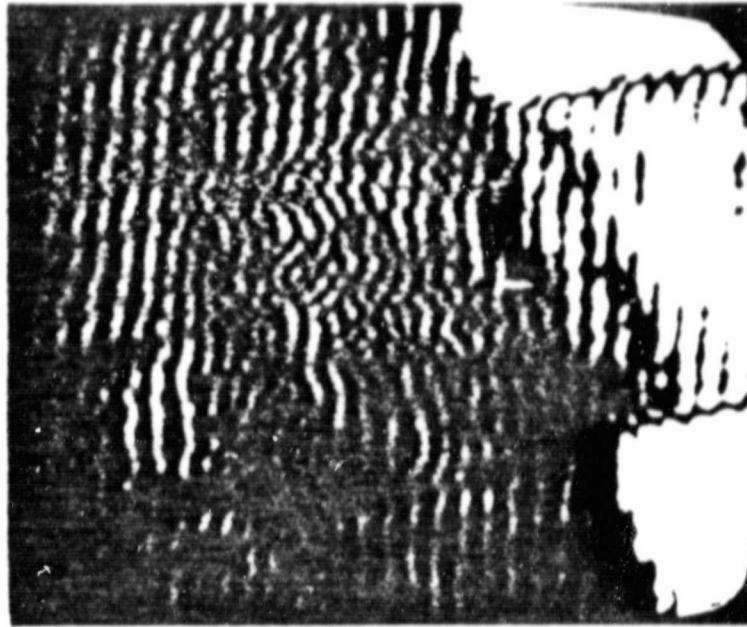


S-30. Both tabs exhibit very good transmission acoustically in the weld area. Area b (bottom) has larger area of contact than a (top).

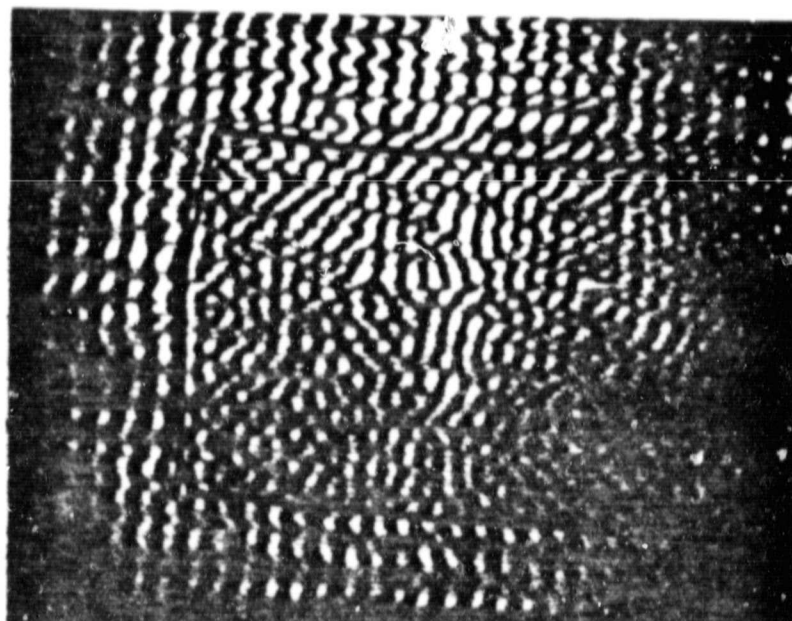
ORIGINAL PAGE IS  
OF POOR QUALITY

#### PHASE IV

The following micrographs were taken on the solar cell labeled C1C1.  
It contained four weld tabs and had a glass cover plate attached by  
RTV. Two of the tabs were welded to the underside of the cell.  
Micrographs were taken on both sides for comparison.



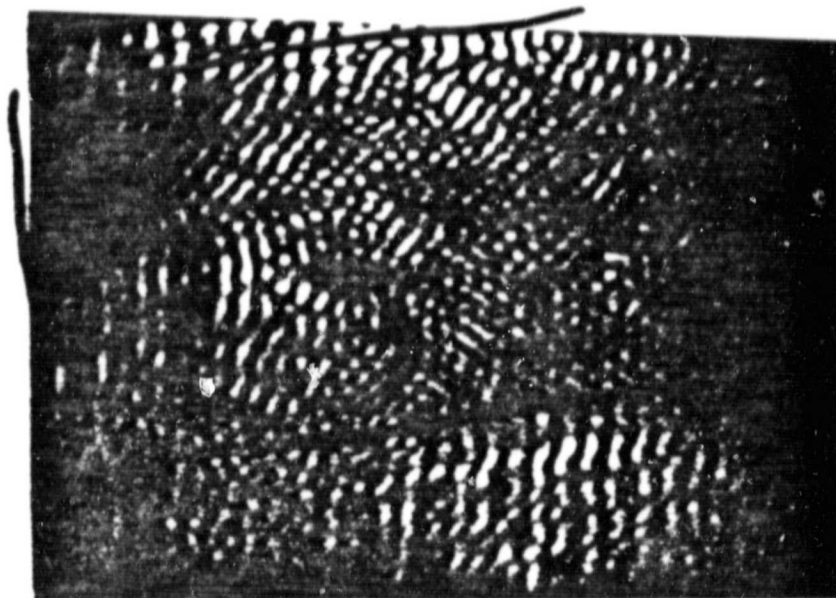
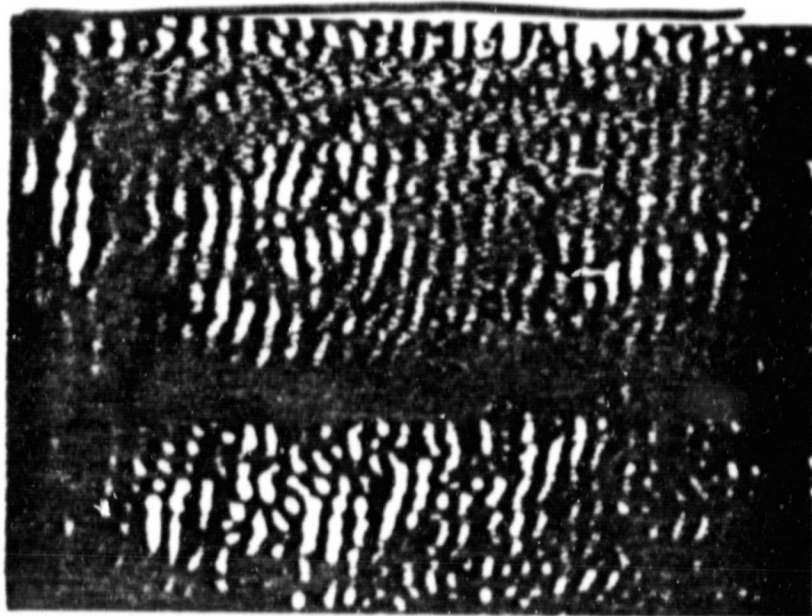
C1C1 a, b These two micrographs were taken on the tabs welded to the top surface. The top micrograph (tab a) exhibits more attenuation than was found in the bottom (tab b). Overall, the level of acoustic transmission is less due to the addition of the glass cover plate.



ORIGINAL PAGE IS  
OF POOR QUALITY

C1C1 c The top micrograph was taken with tab c on the side closest to the coverslip. In the lower micrograph the cell was flipped over and the tab was closer to the transducer. Better definition of the weld is noticed with the tab nearest the detection plane. Mode conversion and reverberation in the glass plate add to the structure and the scrambling of the fringes in the lower micrograph.





C1C1 d      The top micrograph illustrates the tab close to the coverslip and the lower, closer to the transducer. Better transmission occurs in tab d than in c (insonification geometry same as in tab c - see sketches).

ORIGINAL PAGE IS  
OF POOR QUALITY